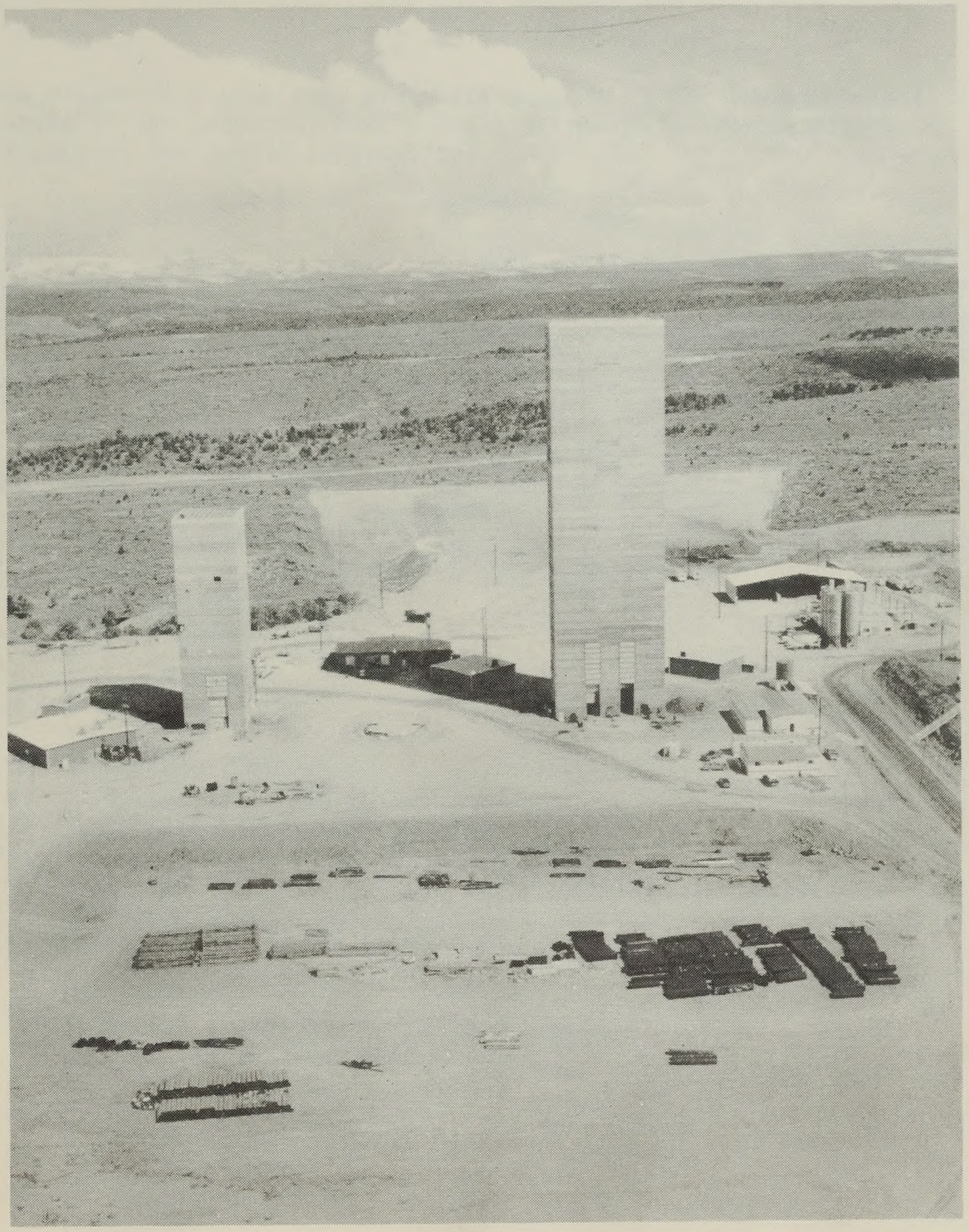
CATHEDRAL BLUFFS SHALE OIL COMPANY



PREVENTION OF SIGNIFICANT DETERIORATION

APRIL 1981

50

OXY INTER-OFFICE MEMORANDUM

TO: PSD Application Holder

FROM: E. T. Foy

PROJECT: C.B.-OOSI

SUBJECT: Errata Sheet

DATE: April 21, 1981

Attached please find your copy of Errata sheet No. 1 for the PSD permit application of The Cathedral Bluffs Shale Oil project. Please attach it to your copy of the permit application.

E. T. Foy

ETF/dln

Attachment

Holder List:

Book No.	
1	W. H. Love and W. F. McDermott
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10,12	CAQCD, c/o G. McCutchen
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36	G. Hobbs (Davis, Grahm, and Stubbs)
37	Ms. Gash (Rio Blanco Oil Shale)
38	L. Harrington (L.E.T.C.)
39	K. Ludeke (Union Oil)
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41,48	J. Wilkenfeld (OPC)
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45	W. Davis
46	J. Allan (Fluor, Houston)
47	C. Lee
49-53	R. Tucker, OSO

OCCIDENTAL OIL SHALE, INC.

April 21, 1981

Errata Submission No. 1, C.B. Commercial PSD Application

Chapter I:
No Corrections

Chapter II:
a) Page II-12, line 20,. . .second precooler exchangers which. . .
b) Page II-17, line 7, . . .These layers will be recovered. . .

Chapter III:
a) Page III-2, line 10, . . .tonnages are in Appendix 1.0. . .
b) Page III-3, line 2, paragraph a, . . .at the rate of 27,950 TPD each. . .
c) Page III-5, line 2, paragraph i, . . .dust generated by each of. . .
d) Page III-5, line 4, paragraph j, . . .conveyers and the transported to. . .
e) Page III-7, line 5, paragraph q, . . .Simultaneously, gypsum. . .

Chapter IV:
a) Page IV-2, line 2, para. 1.4, . . .a rate of 30.4 ton/day. . .
b) Page IV-II, para. 3, . . .of 44 ppm (vol). The result of our assessment is that FMC is the FGD technology chosen as the SO_2 removal process.

Chapter V:
a) Page V-35, The headings for columns on the table should be as follows:

GEP Height (m)	Minimum Length or Width (m)
65.8	9.2
69.4	9.6

b) Page V-43, 2nd line from the bottom, . . .shown on Figure 21 (in section 7.0);. . .

Chapter VI:
a) Page VI-8, line 20, . . .version from $\mu g/m^3$ to. . .
b) Page VI-9, line 22, * Oregon grape
c) Page VI-9, line 5, ** Serviceberry
d) Page VI-10, line 8, ** Snowberry
e) Page VI-11, line 11, ** Darnel
f) Page VI-12, line 34, . . .Phacelia Scorpion weed
g) Page VI-15, line 6, semiarid
h) Page VI-15, line 32, . . .of low concentrations of air. . .
i) Page VI-15, line 33, . . .on the semiarid ecosystems of. . .
j) Page VI-16, line 20, . . .at 20°C (and 1 atm). . .
k) Page VI-16, line 27, . . .difference (alpha = 0.05) between. . .
l) Page VI-16, line 35, . . .are crustose types (Marsh and Nash, 1979).
m) Page VI-19, line 14, . . .cases in Appendix 11 of this. . .
n) Page VI-23, line 14, . . .Appendix for 200 km (. . .
o) Table VI-13 should be augmented as per the attached page.

Chapter VII:

a) Page VII-3, add the following reference:

Marsh, J. E. and T. H. Nash III. 1979. Lichens in Relation to the Four Corners Power Plant in New Mexico. The Bryologist 82(1):20-28.

TABLE VI-13

Values of Blue/Red Ratio, Plume Contrast, and Color Difference Parameter (DELTA E) for Different Line of Sight/Plume Angles

BACKGROUND VISUAL RANGE = 200 km

α	22	30	45	60	90	135	150
B/R Ratio	0.935	0.921	0.925	0.976	0.930	0.925	0.921
Contrast	-0.030	-0.027	-0.014	-0.018	-0.017	-0.014	-0.027
Delta E	3.193	3.522	3.150	2.640	2.771	3.150	3.522

BACKGROUND VISUAL RANGE = 150 km

α	22	30	45	60	90	135	150
B/R Ratio	0.953	0.956	0.919	0.945	0.937	0.919	0.956
Contrast	-0.024	-0.024	-0.020	-0.017	-0.017	-0.020	-0.024
Delta E	2.311	2.926	2.767	2.316	2.535	2.767	2.926

Cathedral Bluffs Shale Oil Company

PSD Permit Application

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BACKGROUND INFORMATION

I.

C-b BACKGROUND INFORMATION

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I. C-b BACKGROUND INFORMATION

1.0 Overview of the Project

The Cathedral Bluffs Shale Oil Project is a joint venture of Occidental Oil Shale, Inc. (OXY), a wholly owned subsidiary of Occidental Petroleum Corporation, and Tenneco Shale Oil Company, a wholly owned subsidiary of the Tenneco Oil Company. The C-b Oil Shale Project began as a joint venture of Ashland Oil, Inc., Atlantic Richfield, TOSCO, and Shell Oil Company. The joint venture was organized to acquire the Federal Oil Shale Lease Tract C-b, under Lease C20341 from the United States, and to develop the reserve subject to the lease. The lease was acquired effective April 1, 1974 for a competitive bonus bid of $117,788,000.36. The lease grants the exclusive right to mine and process oil shale from the approximately 5,094 acres contained in the Tract. In the spring of 1975, TOSCO and ARCO both withdrew from the venture and subsequently, on November 2, 1976, Shell Oil Company withdrew from the C-b Oil Shale Project. On November 2, 1976 Ashland Oil, Inc. announced the formation of a new joint venture with Occidental Oil Shale, Inc. to proceed with development of Tract C-b. On February 14, 1979, Ashland Oil, Inc. withdrew from the C-b Oil Shale Project and Occidental Oil Shale, Inc. continued as operator and holder of the lease. On September 1, 1979, the Cathedral Bluffs Shale Oil Company was formed between Tenneco Shale Oil Company and Occidental Oil Shale, Inc., with OXY as operator in the joint venture between OXY and Tenneco.

The purpose of this document is to obtain a Prevention of Significant Deterioration (PSD) Permit for the commercial project at the C-b Tract by the Cathedral Bluffs Shale Oil Company. This document will provide the detail to demonstrate compliance with 40 CFR 52.21 (d) and Title I Part C of the Clean Air Act Amendments of 1977 (42 USC 7401 et. seq.), that are designed to prevent significant deterioration of air quality. The plant is designed for a stream day capacity of 117,275 barrels-perday and will incorporate both the OXY developed modified in-situ (MIS) process and Above Ground Retorting (AGR) technologies. As required, and as will be detailed in this document, BACT will be designed into the process for control of the waste streams produced by the commerical processes.

The combination of retorting technologies and BACT are demonstrated by the emission modeling assessment to comply with the allowable pollutant

increments allowed by the Act and at the same time providing an overall process configuration that is both technically and economically feasible.

The total barrel-equivalent design production rate from the resource is 155,360 barrels per stream day. The energy production recovered from the operation is approximately 872 billion BTU's per day which would be utilized as follows:

1) Approximately 650 billion BTU's, or 117,275 barrels/day as marketable oil product,
2) An additional 2.2 billion BTU's, or 400 barrels of oil will be used on a daily basis to ignite new in-situ retorts, and
3) Approximately 200 billion BTU's will be recovered from low BTU off-gas, which is equivalent to 37,685 bbl/day of oil. This fuel will be burned in boilers to produce steam for the production of electricity and other in-plant uses. Electricity will supply project requirements and the unused portion will be fed into the domestic power grid.

In summary, at full production this project is energy efficient and on an annual basis, does not require outside sources of electricity other than for emergency purposes. The resource is recovered as liquid and gas products and energy is exported in the form of oil and electricity.

2.0 The C-b Tract

2.1 Area Description

This application is for the commerical development of Tract C-b of the Federal Prototype Oil Shale Leasing Program consisting of 5,093.9 acres, more or less, as is shown on Drawing No. OXY-1 (Appendix 4.0) and is located in Rio Blanco County, Colorado as follows:

T. 3S., R. 96 W., 6th P. M.

Sec. 5, W 1/2 SE 1/4, SW 1/4
Sec. 6, Lots 6 and 7, E 1/2 SW 1/4, SE 1/4
Sec. 7, Lots 1, 2, 3, 4, E 1/2 W 1/2, E 1/2
Sec. 8, W 1/2 NE 1/4, NW 1/4, S 1/2
Sec. 9, SW 1/4
Sec. 16, NW 1/4, W 1/2 SW 1/4

Sec. 17

Sec. 18, Lots 1, 2, 3, 4, E 1/2 W 1/2, E 1/2

T. 3S., R 97W., 6th P. M.

Sec. 1, S 1/2

Sec. 2, SE 1/4

Sec. 11, E 1/2

Sec. 12

Sec. 13, N 1/2

Sec. 14, N 1/2 NE 1/4

The Tract is located in a sparsely populated portion of Rio Blanco County in the Piceance Creek Basin in Northwestern Colorado. Terrain on the Tract consists primarily of undulating valleys and ridges trending in a northeasterly direction and draining into Piceance Creek. The northern edge of the Tract is approximately one-half mile south of Piceance Creek at the confluence with Stewart Gulch. Piceance Creek then flows northwesterly for approximately 24 miles to its confluence with the White River. There are a few scattered ranches along Piceance Creek. The communities nearest to the Tract are Meeker, Rifle, and Rangely, 40, 40, and 60 miles respectively, by paved highway.

Elevations on the Tract vary from 6,400 feet in the lowest valley bottoms, to 7,100 feet on the ridges at the southern edge of the Tract. The climate is semiarid with snow cover occurring variably from October to May. The climate supports sparse vegetation, with sagebrush and pinyon-juniper communities being dominant. Approximately 45% of the Tract (primarily the flat ridge tops) was chained by the Federal Government in 1967. Chaining is a technique designed to improve range production by knocking down the standing sage and pinyon-juniper. Historically, the Tract has been used for cattle grazing and providing winter range for mule deer.

2.2 Location of Oil Shale

The oil shale resources are located in the Parachute Creek member of the Green River Formation beneath the Tract. The oil shale is contained in essentially horizontal sedimentary beds of varying richness. The total thickness of these beds is about 2,100 feet. Other minerals such as nahcolite

and dawsonite, which occur in abundance in the north-central part of the Piceance Creek basin, do not occur in significant amounts in the zone presently being considered for processing.

The project is presently designed to process the shale in a zone that is approximatley 300 feet thick. This incorporates those richer zones of shale having average oil contents ranging from about 26 to 32 gallons-per-ton. By using both MIS and AGR technologies, the highest percentage of resource recovery is achieved without adverse impact on the surrounding region.

2.3 Federal Lease and Lease Requirements

On April 1, 1974, a joint venture of Ashland Oil, Inc., Atlantic Richfield Company, TOSCO, and Shell Oil Company acquired Federal Oil Shale Lease Tract C-b (C20341) for a competitive bonus bid of $117,788,000.36. The Lease, part of the Federal Prototype Oil Shale Leasing Program, was motivated by the need to assist the development of the oil shale industry in a closely monitored and controlled phase to accumulate environmental information and test alternative technologies. All phases of the development are being, or will be, monitored. On February 9, 1976, the C-b Oil Shale Project submitted its Detailed Development Plan (DDP) to the Area Oil Shale Supervisor (AOSS) for approval in accordance with the terms and conditions of the Lease.

On April 1, 1976, the C-b Oil Shale project paid the third installment of $23,557,600.08 under the Terms of the Lease. This lease grants ......"the exclusive right and privilege to prospect for, mine by underground or surface means and process by retorting or by insitu methods or otherwise, as he may reasonably choose, and in accordance with approved plans......".

In February of 1977, a Modified DDP was submitted to the AOSS to resolve certain issues raised by the AOSS concerning the original DDP and to reflect the change of processing philosophy that came about as a result of Occidental Oil, Inc., joining the venture. The issues which were raised by the AOSS did result in a suspension of operations for one year, starting September 1, 1976.

On February 14, 1979, Ashland Oil, Inc. withdrew from the venture, leaving Occidental Oil Shale, Inc. as the operator and holder of the lease.

On September 1, 1979, the Tenneco Shale Oil Company joined the Tract C-b venture. The joint venture between Occidental and Tenneco was incorporated as the Cathedral Bluffs Shale Oil Company and, as such, they are co-holders of the Lease. Occidental Oil Shale, Inc., has continued as operator of the venture.

The Federal lease for Tract C-b requires that environmental responsibility be a high priority concern of the Lessee. The lease has a number of very specific requirements such as, (a) the lessee shall comply with all applicable Federal, State, and local water pollution control, water quality, air pollution control, air quality, noise control, and land reclamation statutes, regulations, and standards, (b) the lessee shall minimize or, where practical, repair damage to the environment, including the land, water, and air, and (c) a list of environmental stipulations requiring monitoring and special conditions to be complied with by the lessee and any sub-contractors. The requirements are very comprehensive and designed to insure compliance with existing law and to monitor effects upon the environment.

2.4 Approval of Conditional PSD Application

On December 15, 1977 the EPA issued a Conditional Prevention of Significant Deterioration Permit (Appendix 12.0) covering the ancillary phase of the project. This conditional permit covers the first phase of operations which may lead to full commercial operation. The ancillary phase, covers the site preparation, shaft sinking, and MIS retorting of six underground units, extending over a time period from the date of issuance until about 1982. Specific activities covered by this conditional permit include general site preparation, the sinking of four shafts, and the operation of a two retort module and a four retort module, the larger of which is designed to produce about 5,000 barrels a day shale oil. Construction of other on-site support facilities is also allowed in the permit.

Construction on the Tract commenced in January of 1978. As of January 1, 1981 the following has been accomplished:

1) A 29-foot diameter production shaft had been sunk to a depth of 1,606 feet
2) A 34-foot diameter service shaft had been sunk to a depth of 1,522 feet.
3) A 15-foot diameter ventilation escape shaft had been sunk to a depth of 1,302 feet.

4) Seven warehouse and storage buildings have been constructed.

5) A cement batch plant has been constructed and permitted by the State of Colorado as a point source.

6) A number of trailers are on site, providing office and laboratory space.

7) Three ponds have been put into service for water management and as part of the water reinjection and surface application systems.

8) Other mine and site related structures of various descriptions are also on site. A detailed itemization of these facilities can be obtained from the Area Oil Shale Office. This information is contained in the annual report submitted to this office annually.

II SOURCE DESCRIPTION

II.

SOURCE DESCRIPTION

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II SOURCE DESCRIPTION

1.0 Construction Schedule

The major milestone schedule for MIS, with lightoff of the first retorts in mid-1985, and above ground retorting (AGR), is as follows:

- Release of detailed engineering in 1981
- Release of critical equipment procurement by late in 1981
- AGR Trains #1 & 2, mid 1984
- Mechanical completion of surface process facility (SPF) Train #1 1985
- Ignite first MIS Retort, Late 1985
- Mechanical completion of SPF Trains #2, 1988
- AGR Train #3, 4, 5 and 6, early 1988
- Mechanical completion of SPF Trains #3, early 1989
- AGR Trains #7 & 8, early 1989
- Mechanical completion of SPF Trains #4 and 5, 1990

Full production is scheduled to occur in 1991 with a total MIS oil production rate of 68,975 B/SD. Full AGR production will occur in 1990 at a total production rate of approximately 48,300 B/SD.

2.0 Overall Process Configuration With Flue Gas Desulfurization

2.1 Description

A schematic flow diagram of the commercial Surface Process Facilities (SPF) for a Flue Gas Desulfurization (FGD) configuration is shown in Figure II-1. Component material balances for the major streams are given in Table II-1. The material balances are based on five operating MIS offgas trains.

Retort Gas

The low-Btu Modified In-Situ (MIS) retort offgas is received at the Surface Process Facilities at 8.0 psia (3.4 psi vacuum) and 150°F through

an underground shaft. This gas flow is split among five parallel gas trains. Each train is designed to process 20 percent of the normal MIS gas flow on a long term basis. Each train will be designed for a short term maximum capacity of 25% of the total MIS gas flow.

Combination Precooler/Ammonia Scrubber

The FGD case incorporates combination precooler/ammonia scrubber towers ahead of the offgas blowers. The washed and compressed MIS off-gas is sent (about 225°F) directly to special low-pressure burners in modular steam boilers.

600 psig Modular Steam Plant

All of the available MIS offgas, Phosam Acid Gas, and the Above Ground Retort (AGR) product gas are used to produce 600 psig, 750°F steam in boilers. Part of the 600 psig steam is sent to extraction turbogenerators for the production of electricity, while the rest is used for steam turbine drivers.

Flue Gas Desulfurization

Each boiler has an induced draft fan to provide sufficient draft to balance boiler furnace pressure and sufficient pressure to force the flue gas through the flue gas desulfurization absorbers.
In the FGD process, the flue gas is contacted with a basic reagent, depending upon the process chosen. The SO_2 is reduced to approximately 5% of the FGD inlet concentration by a basic reagent.

Ammonia Strippers

Process condensate recovered in the combination precooler/ammonia scrubber towers along with recycle wash water are steam stripped in an ammonia stripper. Ammonia, H_2S, CO_2, oils, and volatile soluble organics are removed. About one-half of the stripped condensate is recycled to the combination precooler/ammonia scrubber, and the net deaerated condensate is sent to low-pressure (240 psig) process steam evaporators.

Phosam Units

The "Phosam W" process is U.S. Steel's proprietary process for recovery of high-quality fertilizer-grade anhydrous ammonia from wet ammonia-rich gases. Water from the bottom of the retort is steam stripped in the retort water treatment facility. These steam stripper vapors and the ammonia stripper overhead gas vapors are sent to the Phosam units for ammonia recovery.

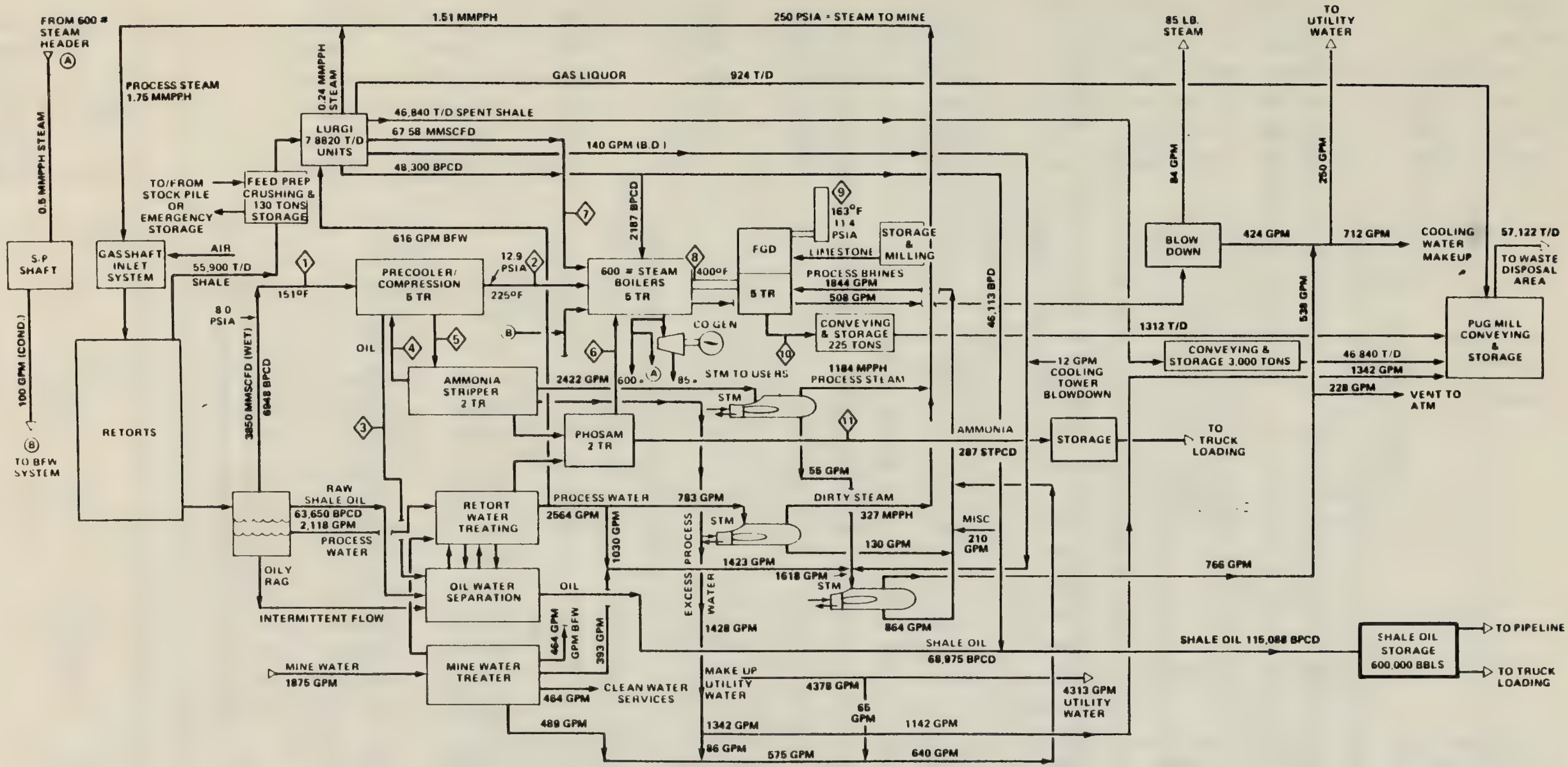

FIGURE II–1
COGENERATION OF STEAM AND POWER
MIS RETORTING AND SURFACE RETORTING INTERFACE
(FOR OPERATION OF FIVE SURFACE PROCESS LINES PLUS SEVEN LURGI LINES)

OVERALL PROCESS MATERIAL BALANCE

MIS RETORTING PLUS SURFACE RETORTING INTERFACE

TABLE II-1

(Quantities Are For Five Operating Surface Process Lines Plus Seven Operating Lurgi Lines)

COMPONENT	MIS OFFGAS % VOLUME DRY	1 MIS OFFGAS LB. MOL PER HOUR	2 COMPRESSED OFFGAS	3 CONDENSED LIGHT OIL	4 STRIPPED PROCESS CONDENSATE	5 AMMONIA RICH WATER	6 PHOSAM ACID GAS	7 LURGI PRODUCT GAS	8 BOILER FLUE GAS	9 FGD STACK GAS	10 FGD SLUDGE	11 ANHYDROUS AMMONIA
H_2	9.397	27,519.5	27,519.5					2,336.9				
N_2	60.640	177,584.4	177,584.4					230.0	407,681.8	407,681.8		
CO	1.750	5,124.5	5,124.5					200.3				
CH_4	1.610	4,715.3	4,715.3					1,112.9				
C_2=	0.120	350.8	350.8					333.9				
C_2	0.257	751.3	751.3					400.6				
CO_2	24.972	73,128.0	72,430.0			698.0	1,117.6	1,868.1	98,446.6	98,446.6		
H_2S (SO_2)	0.174	508.6	503.9		1.9	6.6		5.2	(535.4)	(26.8)		
C_3=	0.080	233.9	233.9					341.3				
C_3	0.120	350.8	350.8					215.2				
NH_3	0.580	1,698.4	579.1		33.1	1,152.4	22.1	18.5				1,405.4
C_4 + Plus Light Oil	0.292	855.0	336.1	518.9			20.8	356.1				
COS	0.005	14.6	14.6					-				
CS_2	0.001	2.9	2.9					-				
CH_3SH	0.002	5.9	5.9					-				
O_2	-	-	-					-	11,550.3	11,550.3		
$CaSO_4 \cdot 2H_2O$	-	-	-					-			508.6	
TOTALS M/HR (DRY)		292,843.9	290,503.0	518.9	35.0	1,857.0	1,160.5	7,419.0	518,214.1	517,705.5	508.6	1,405.4
H_2O M/HR		130,415.0	26,458.5	15.4	69,645	173,586.1	781.5	Ø	89,245.8	138,175.6	1,215.2	7.4
TOTAL M/HR (WET)		423,258.9	316,961.5	534.3	69,680	175,443.1	1,942.0	7,419.0	607,459.9	655,881.1	1,723.7	1,412.8
TOTAL LB/HR (WET)		10,998,331	9,019,765	86,955	1,254,237	3,175,008	64,824	185,616	17,757,040	18,605,226	109,353	24,025
MMSCFD (GPM)		3,850	2,883	(203)	(2,510)	(6,253)	17.7	67.58	5,525	5,966		(71.3)
TEMP. °F (PRESS. PSIA)		151(8.0)	225(12.9)	108(132)	95(100)	93(55)	193(12.9)	95(12.7)	400(11.4)	163(11.4)	-	111(250)

The tail gas from the top of the Phosam absorber joins the boiler fuel gas.

Process Steam Evaporators

Stripped process condensate is sent to steam-heated kettle evaporators to produce most of the 240 psig saturated process steam required for the MIS retort operation. The 300 psig steam required in the tubeside of the kettles is supplied by exhaust steam from process turbine drivers.

Dirty Steam Evaporators

The retort process water is treated for oil and sludge removal, steam stripped and sent to the steam kettle evaporators for production of the remainder of the 240 psig process steam required by the MIS retort operation.

Water Evaporators

Some retort process water, blowdowns from the process steam evaporators and high pressure steam boilers, as well as brine from the retort water treating system and other aqueous streams are concentrated in steam kettle boilers. The effluent brine concentrate joins other aqueous streams in route to the FGD system. The advanced FGD systems can accept process brines as the makeup fluid. Part of the water provides evaporative cooling of the 400°F flue gas and the rest (including the TDS and organics) is fixed into the solid byproduct. This product will be mixed with the spent shale from surface retorting units.

Above Ground Retorting (AGR)

The oil shale rock hoisted to the surface is retorted in 8000 metric ton/day above ground retorts (AGR). The Lurgi process is used as the design AGR process. Of eight units, one will be in a stand-by mode which results in seven units operating at full capacity for 365 days/year.

3.0 Plant Layout

3.1 C-b Tract Plot Plan

Drawing EM-102 (Appendix 4.0) is an overall plot plan for the entire Tract C-b. All the major facilities are located on the Tract as are the location of the raw and spent shale piles and the top soil storage piles.

3.2 MIS Gas Processing Facilities

Drawing 650239-4-00-001-VB (Appendix 4.0) is an overall plot plan for the MIS surface process facilities. The various emission sources and types are shown for different areas such as flue gas desulfurization stacks

and the oil storage area. Additional drawings of the surface process facilities (Appendix 4.0) are:

Plot Plan Scrubber Area	- 65-239-4-050
Plot Plan - Boiler Area	- 650239-4-051
Plot Plan - FGD Area	- 650239-4-052
Plot Plan - Process Condensate Treating and Phosam Facilities	- 650239-4-056

3.3 Shale Handling Facilities

Drawing EM-106 (Appendix 4.0) is an overall plot plan of the shale handling facilities. All the shale handling facilities for shale processing are shown. This includes movement of shale from the production shaft to the surface retort and disposal of spent shale.

3.4 Above Ground Retorting (AGR)

Figure II-2 is an overall plot plan for an eight unit AGR facility. In this permit application, the Lurgi is the basis for emission locations, factors, and other necessary information.

4.0 Process Descriptions

4.1 Raw Shale Storage Stockpile and Handling

4.1.1 Production Quantities

Raw shale produced from mine development activities will be hoisted to the surface for either immediate or eventual processing in the surface retorts. Material produced before the retorts individually come on line will be stockpiled; but thereafter, only such production in excess of the on line retorting capacity will be added to the stockpile. The stockpile will reach a maximum size of some 60 million tons of raw shale with a volume density (33 percent voids) of 19.7 cubic feet per ton. The surface retorts will be fed with shale from the mine and the stockpile until the stockpile has been fully consumed in the year 2011.

Raw shale production builds up rapidly at a maximum rate of 59,000 TPD in 1988, continues at this level until phase II of the project operation is reached in 1990, and then is reduced to 55,900 TPD. All seven surface retorts are in operation at this time, resulting in an average of

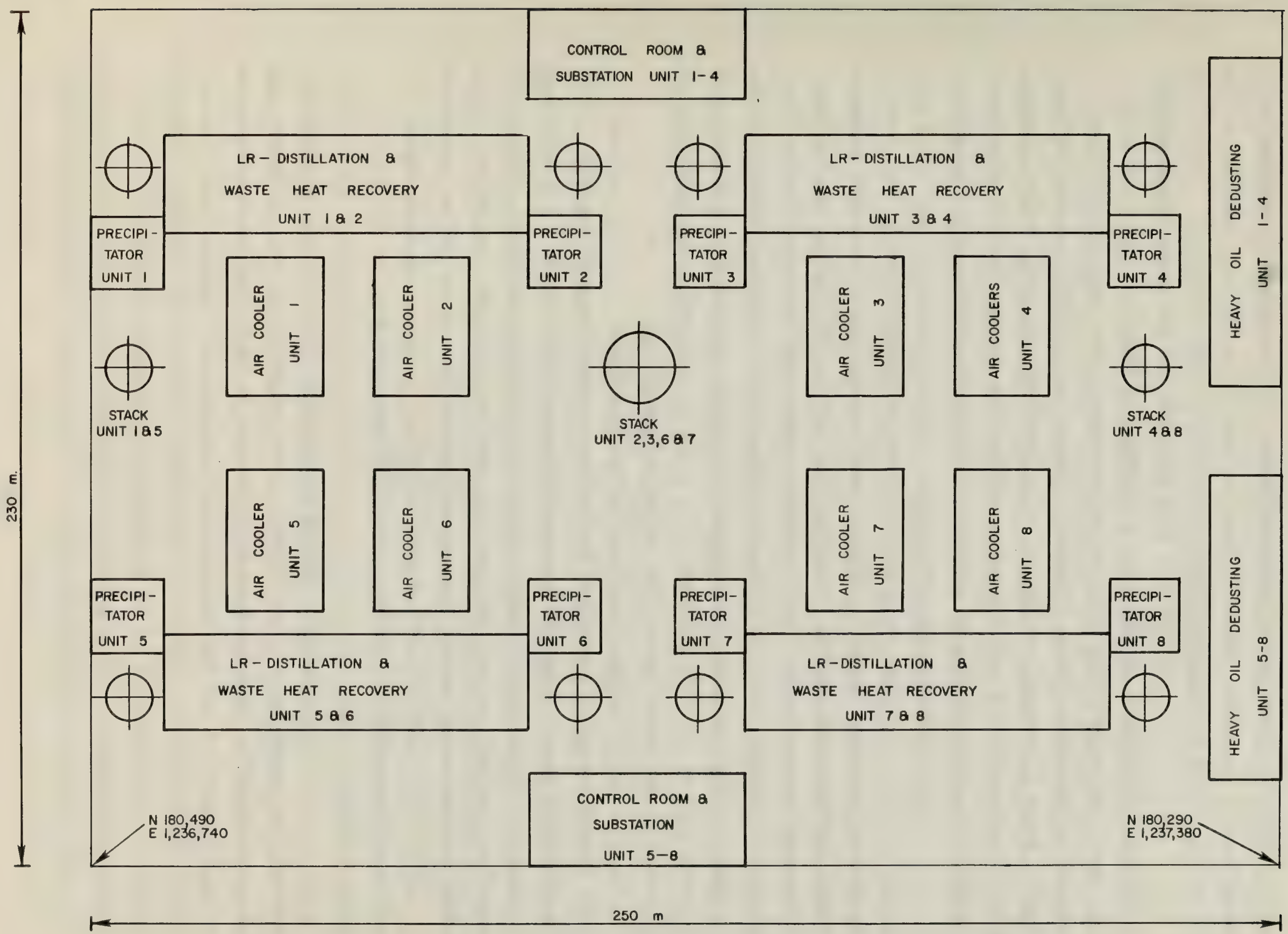

FIGURE II-2

LURGI - RUHRGAS (AGR) PRELIMINARY PLOT PLAN

about 5,800 TPD of raw shale being reclaimed from the stockpile to feed the retorts.

4.1.2 Storage Site

The 300 acre area selected for the raw shale stockpile is depicted on Drawing EM-102, Rev. C (Appendix 4.0). This 2,800 by 4,700 foot area lies in the lower reaches of Cottonwood Gulch near the northern boundary of the lease tract. Its near side is about 1,500 feet and its far side is about 5,000 feet, northeast of the production shaft. The raw shale pile is designed for 1 to 4 slopes on all but the northern most side which slopes at the angle of repose and will be reclaimed shortly after formation.

4.1.3 Handling Practices

Raw shale from the mine is dumped directly into receiving hoppers provided in the headframe tower for the production shaft. Apron feeders withdraw the material from these hoppers and discharge it onto a pair of covered conveyor belts. At a transfer point along the pair of belts, the material is diverted onto belts feeding the surface retorting facility. The remainder of the raw shale in excess of retorting requirements is diverted to a single covered belt for movement to a truck loadout hopper bin, initially located near the south toe of the raw shale stockpile.

The stockpile will be extended at its full east-west width down the sloping topography toward the northern edge of the pile. As the stockpile grows, a partially-covered conveyor and loadout bin will be added to extend northerly, to reduce the truck haulage of raw shale. Trucks will dump along the edge of the embankment to both the east and west of this centrally located and extended conveyor and loadout bin. A sprinkler system will be available to control fugitive dust emissions. Graders, dozers, and/or front-end loaders will be used to level and shape the pile to its final configuration.

Top soil will be stripped from the surface immediately ahead of the advancing pile and stored at convenient locations around the periphery of the pile. Two scrapers will be used for such operations at both the raw shale stockpile and the spent shale disposal area. Top soil will be replaced on a continuing basis over the leveled, shaped, and otherwise completed sections of the stockpile so as to insure that no more than 15 acres of the advancing embankment will be exposed to wind erosion. Raw oil shale, once the dust from mining and crushing is washed off, thereafter, remains remarkably

clean and fresh, and hence, is little affected by wind erosion. Revegetation of the replaced top soil will occur at about 6 month intervals, depending on the season. Irrigation and fertilization will be needed until the vegetation is well established.

Reclaiming of the stockpiled raw shale for retorting will begin by movement of raw shale from the north end of the pile. The consumption of the stockpiled raw shale will then progress to the south. The deeper northern sections will be worked in benches extending across the full width of the pile. Front-end loaders, or motor scrapers, will be used to load the stockpiled material into trucks for haulage to a conveyor hopper that in turn would feed a covered conveyor extending to the transfer tower.

Truck haulage roads for such operations will be located on either the east or west side of the stockpile. Water sprays will be provided for dust control during haulage in reclaiming the stockpiled material. The originally replaced and revegetated top soil on the stockpile again will be restripped in advance of the reclaiming operations and stored at convenient locations for ultimate replacement and revegetation over the original land surface below the stockpile.

4.1.4 Raw Shale Processing

Processing of the raw shale hoisted to the surface will follow the flow scheme as diagramatically illustrated on Drawing EM-101, (Appendix 4.0). Raw shale is taken by conveyor from the stacking towers to the crushing and screening building. Upon entering the building, the raw shale is screened. The fines (<1/4" diam.) are sent on for retorting. The 2" to 1/4" material is sent to teritiary crushing, and the 2"+ material is fed to the secondary crushers.

The secondary crushing product is screened with 2"+ material being recycled back for secondary crushing, the fines being sent to retorting, and the 2" to 1/4" material being sent to a conveyor transfer tower and on to the tertiary crushers. The tertiary crushing product is again screened and the 2" to 1/4" material is returned to be fed to the tertiary crushers again and the fine material is conveyed from the bins to the Lurgi Surface Processing Facility for retorting to shale oil.

4.1.5 Processing Flow Diagram

Drawing EM-101 (Appendix 4.0) is a flow diagram of the processing scheme. It depicts each step from the production shaft to disposal of the spent shale. Drawing MSK-13 (Appendix 1.0) also provides a flow

scheme of The Solid Material Handling System and includes a material balance of that system.

4.2 MIS Gas Scrubbing & Compression

4.2.1 Description (Figure II-4.1)

The primary function of the offgas compression and scrubbing section of the commercial Surface Process Facilities (SPF) is to recover water and oil and then boost the pressure of the low-Btu retort offgas sufficiently to deliver the offgas to the burners of the steam boilers for combustion. Offgas is available at 8.0 psia (3.4 psi vacuum) and 150°F with about 30 volume percent water vapor. The combination of the offgas precooler and ammonia scrubber condenses about 3900 gpm of process condensate, including light oil, with a reduction in ammonia in the retort offgas. Light shale oil is also recovered from the offgas during this water scrubbing operation.

Offgas compression and scrubbing is the first step in the surface processing system of the five parallel gas trains. Each train has been designed with a maximum short-term capacity to handle 25 percent of the total normal offgas flowrate. The process flow diagram (Figure II-4.1) depicts one of these trains. The flows associated with this train are shown on the material balance in Table II-4.1.

The five parallel trains will permit an onstream factor close to 1.0, thus assuring a high level of reliability. Normally, all five trains designed for a yearly on-stream capacity of 20% of the total offgas flow will operate continuously, splitting the available flow. Major turnarounds will be scheduled to the extent possible for spring and fall, when temperatures are more moderate. This should minimize the number and duration of offgas flow restrictions during summer peak ambients and avoid inadvertent winter freeze-ups (since large quantities of warm water are being circulated through airfan coolers). Additionally, steam turbine blower drives are provided on all trains because of the high reliability provided by the steam systems.

In the configuration, the process gas shaft (about 34 foot inside diameter) conveys the 3.85 billion standard cubic feet per stream day (SCFD) of wet retort offgas from the underground headers on the operating retorts to a shaft collar house located at the top of the shaft at ground level. The offgas is expected to arrive at the shaft collar house at a

pressure of about 8.0 psia (3.4 psi vacuum). Temperatures of about 150° are expected and moisture content is anticipated to be about 31 percent by volume (wet/dry ratio of 1.45).

At the 20 percent operating rate, 770 MMSCFD of retort offgas enters the battery limits of each offgas compression and scrubbing train through an approximately 13-foot duct (pressure is about 7.9 psia). A knife gate valve is located at the battery limits of each offgas compression and scrubbing train to permit isolation of each train from the rest of the Surface Process Facilities. Also at the inlet of each compression train, an inlet flow control butterfly valve is used to balance the flow among all operating trains, in conjunction with speed and/or vane controls on the blowers. Balancing is required in part due to the distance of each train from the gas shaft and the variable pressure drops which will develop if fouling occurs on equipment. These valves will normally run nearly open and will provide trim to obtain the desired suction flow to the retort offgas blowers, while holding the shaft collar pressure relatively stable at 8.0 psia. Should the pressure at the gas shaft collar rise, the damper valves will be automatically reset for higher flowrates.

Upstream of the retort offgas blowers, the retort offgas is contacted countercurrently with cool condensate in the ammonia scrubbing section of the combination precooler/scrubber tower. Heat of absorption for ammonia is removed via four stages of side cooling and the offgas exits the scrubber at a temperature of 85°F. In addition to cooling the retort offgas and removing ammonia, the ammonia scrubbers remove mist particles. As a result of gas cooling, in both the precooling and scrubbing sections, 748 gpm of water vapor and about 1392 BPSD (Barrels-Per-Stream-Day) light shale oil are condensed in each train from the retort offgas. The process condensate from the precooler provides a source of useable water to the SPF and recovers much of the condensible portion of the produced shale oil entrained in the offgas. The noncondensed hydrocarbons assist in maintaining the heat content of the offgas sufficiently high to support combustion in the boilers. The ammonia scrubbers recover about 47 tons per day of ammonia per train in conjunction with the phosam unit.

The precooler ammonia scrubbers are vertical packed towers that are essentially two towers, one stacked on top of the other. The bottom precooler section contains two packed beds where the retort offgas is

cooled and partially scrubbed by the contact with circulating air-cooled water. The primary function of the bottom section is to recover water vapor and condensible light shale oil. While some ammonia is removed in the pre-cooler, the bulk of the ammonia is removed in the scrubbing section of the combination tower.

Referring to the process flow diagram (Figure II-4.1), the offgas enters the bottom of the tower through a gas distributor and flows to a 3-foot bed of grid packing. Grid packing provides low pressure drop and high mass transfer per volume. This results in lower blower energy requirements at a given capacity. In the bottom section of grid packing, the offgas temperature is lowered to its dew point of 131°F by circulating water from the bottom of the pre-cooler ammonia scrubber through the first precooler exchanger. This air cooler lowers the temperature of the water to 95°F. The water is then distributed over the bottom section of grid. The pressure drop of the gas rising through this packed section is about 1" H_2O (0.04 psi).

The saturated retort offgas, at 131°F, then flows through about 22 feet of grid packing reducing the offgas temperature to 85°F. About 400 MM Btu/hr of heat per train must be removed from the offgas at relatively low temperatures (85-90°F). This is accomplished by circulating about 24,500 gpm of water through the second precooler exchanges which lowers the water temperature from 110° to 75°F. The second precooler exchanger can be operated as a wet surface type air cooler during the summer. Water may be sprayed over exchanger tubes to lower the air temperature to its wet bulb temperature (Niagara) or ambient air can be evaporatively precooled, (Hudson Combinaire). On a peak summer day, air temperature of 87°F can be lowered to the design wet bulb of 62°F by use of a wet surface type air cooler.

The water leaving the precooler exchanger is distributed over the top of the 22-foot packed bed inside the precooler. This 22 foot bed is divided into two 11-foot sections to allow for redistribution of liquid flows and to meet packing structural requirements. In addition to water and oil condensation and gas cooling, the ammonia concentration in the offgas is reduced. The pressure drop of the gas rising through this 22 feet of packing is estimated at about 8" H_2O (0.3 psi). The 24,500 gpm of water circulated along with the condensed oil and water absorbed ammonia, internally bypasses the lower 3-foot bed to the bottom of the precooler-ammonia scrubber where it combines with the water from the lower packed section. The bottom of the

precooler provides some residence time for oil and water separation and surge time for level control. Oil separated from the water overflows a weir and is gravity drained on level control. The condensed water is withdrawn from the precooler via oil-water interface level control.

The primary function of the top section of the precooler-ammonia absorber is to reduce the ammonia concentration in the offgas. Approximately 500 gpm of stripped process condensate is required per train to scrub the ammonia from the offgas. This water is supplied at 95°F from water management and is cooled to 75°F in the precooler exchanger. The precooler exchanger is also a wet surface air cooler. The outlet temperature of the precooler is controlled to maintain an 85°F gas temperature leaving the top of the ammonia scrubber. Part of the heat removed by the circulating water included the heat of solution of ammonia.

The water and absorbed ammonia from the top section of the precooler scrubber are combined with the condensed water and entrained light shale oil from the bottom of the precooler scrubber. This mixture then flows to the Oil-Water Coalescers for removal of emulsified oils. Ammonia-rich water flows from the coalescers to the ammonia stripper.

Light shale oil, including entrained water from the bottom of the precoolers, goes to the Light Oil-Water Separators. The separators are gravity type tilted plate separators.

Net light shale oil is pumped by the Separator Light Oil Pumps to the water management section where this oil joins the raw crude shale oil from the modified in situ (MIS) retorts for processing. Water separated from the light oil (about 1-2 gpm) is pumped to the Oily Water Coalescer for eventual treatment in the ammonia stripper.

The offgas, flowing through the three 6-foot beds in the top ammonia scrubber, sustains a pressure drop of about 0.3 psi (8-9" H_2O). Before leaving the precooler, the gas passes through a section of Chevron-type demisters to remove entrained water. The Chevron-type demisters are intermittently water washed at high rates and continuously at low rates by spray headers above and below the demister section. The MIS offgas leaves the precoolers at a pressure of 6.9 psia and a temperature of about 85°F. During winter, temperatures may drop below 85°F, which will enhance ammonia removal, recover additional water and light oil from the retort offgas, and lower the horsepower required by the offgas blowers.

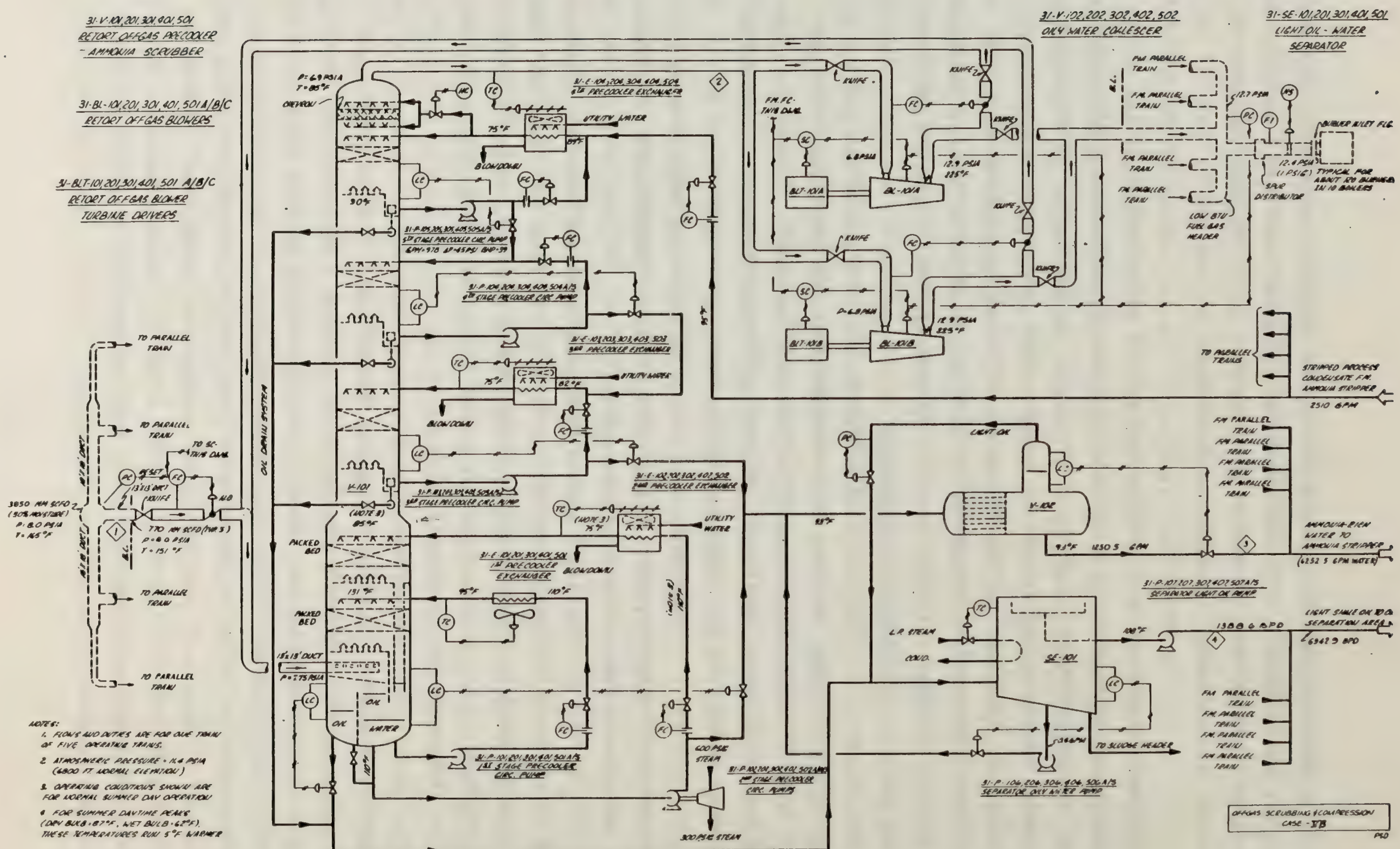

FIGURE II-4.1 PROCESS FLOW DIAGRAM
OFFGAS SCRUBBING & COMPRESSION
COMMERCIAL SURFACE PROCESS FACILITIES

OFF GAS SCRUBBING & COMPRESSION PROCESS MATERIAL BALANCE

(Quantities are for One of Five Operating Trains)

MIS RETORTING AND

MIS RETORTING AND SURFACE RETORTING INTERFACE

TABLE II-4.1

STREAM / COMPONENT	1 MIS RETORT OFF GAS	2 PRECOOLED RETORT OFF GAS	3 AMMONIA RICH WATER	4 LIGHT OIL TO HEATER TREATER
H_2	5,503.9	5,503.9	---	---
N_2	35,516.9	35,516.9	---	---
CO	1,024.9	1,024.9	---	---
C_1	943.1	943.1	---	---
$C_2^{=}$	70.2	70.2	---	---
C_2	150.3	150.3	---	---
CO_2	14,625.6	14,486.0	139.6	---
H_2S	101.7	100.8	1.3	---
$C_3^{=}$	46.8	46.8	---	---
C_3	70.2	70.2	---	---
NH_3	339.7	115.8	230.5	---
C_4 + LT. OIL	171.0	67.2	---	103.8
COS	2.9	2.9	---	---
CS_2	0.6	0.6	---	---
CH_3SH	1.2	1.2	---	---
TOTAL MOL/HR (DRY)	58,569.	58,100.8	371.4	103.8
H_2O, MOL/HR	26,083.0	5,291.7	34,713.8	3.1
TOTAL MOL/HR (WET)	84,651.7	63,392.3	35,085.2	106.9
LB/HR (WET)	2,199,666.3	1,803,953.0	634,943.0	17,391.0
MMSCFD (GPM)	770.0	576.5	(1,250.5)	(40.5)
TEMP °F (PRESS, PSIA)	151 (8.0)	85 (6.9)	93 (55)	108 (132)

The water and oil condensed in the precoolers reduces the flowrate of retort offgas in each train from 770 MMSCFD to about 577 MMSCFD. Cooled offgas flows to the two parallel retort offgas blowers in each train via a 14-foot square duct. This duct splits to two 10-foot square ducts before swagging down to the suction of each blower. The offgas blowers may be designed either as vertically split two-stage centrifugal compressors, as five stage axial fans, or as large single-stage blowers. Each blower has valves at suction and discharge to allow for maintenance without shutting down the entire train. Each blower will produce a differential pressure of 6.1 psi (compression ratio of 1.9).

Compressor differential pressure is determined by the discharge pressure required to supply a steady 1.0 psig fuel gas pressure at the burner flanges of the special low-Btu fuel gas burners in the steam boilers. The discharges of the blowers flow to the low-Btu fuel gas header in a 13-foot square duct.

The retort offgas blowers are driven by 600 psig steam turbines. This assures the overall reliability of the offgas compression and scrubbing section of the Surface Processing Facilities in the unlikely event of a power failure. Steam turbine drivers exhaust at about 4.5 inches of mercury to air-cooled surface condensers. The clean condensate is returned to the boiler feed water deaerator.

From the blowers, the 225°F MIS offgas flows directly to the low-Btu fuel gas header for distribution to the ten 600 psig steam boilers.

4.3 Ammonia Stripping And Recovery (Phosam)

4.3.1 Description (Figure II-4.2)

Process condensate is defined as the water condensed out of the retort offgas during precooling upstream of the blowers. As recovered, this water is relatively corrosive due to the concentrations of dissolved ammonia, hydrogen sulfide, carbon dioxide and volatile dissolved organics. In addition, the process condensate will contain small amounts of minerals from fine mist entrained in the MIS retort offgas. Suspended condensable shale oils and some trace of heavy shale oil from the mist will also be present.

Two parallel trains (Figure II-4.2) are provided for ammonia stripping and recovery of the process condensate from all five gas scrubbing and compression trains. After separation, the process condensate is

steam stripped to recover ammonia, to remove the corrosive dissolved gases, and to remove volatile organics. Volatile organics include soluble light oils washed from the MIS offgas and fine suspensions in the micron and submicron range of light shale oil from MIS offgas condensables and mist. The conditions in the ammonia strippers may also result in a heavier shale oil layer collecting in the tower bottoms and in the partial condensor reflux drum. These layers wil be recovered and sent to the oil separation system. The stripper overhead vapors, consisting of ammonia, H_2S, CO_2, trace oxygen, volatile organics, and steam are sent to the two 75 percent capacity Phosam units. Table II-4.2 presents a total material balance for the ammonia stripping and recovery section.

The stripped process condensate, possibly with some adjustment in pH and some chemical additive injection, is sent to the 240 psig unfired steam generators. As configured, these steam generators are large reboilers, using 300 psig steam. The kettles boil the process condensate under pressure. This equipment is designed to minimize fouling and corrosion. Continuous, plus high-rate intermittent kettle blowdown systems are used to control total dissolved solids and remove any build-up of suspended material and oils. The blowdowns are sent to FGD water makeup and spent shale wetting.

In the ammonia strippers, raw process condensate from the compression unit is first preheated by exchange with the hot stripper bottoms. This reduces the heating steam required in the stripping process and eases handling downstream. Approximately 745,800 lb/hr of steam (2.0 pounds of steam per gallon of condensate) are needed to adequately strip the condensate. After stripping, a part of the process condensate is pumped to the process condensate steam generators. Some of the remaining process condensate is cooled to 95°F and sent back to the top stage of the combination precooler ammonia scrubber tower as wash water in the gas scrubbing process (recovery of ammonia from the offgas), and the remaining process condensate is sent to the condensate storage tank.

The ammonia-rich sour steam vapor from the overhead of the ammonia strippers joins the ammonia-rich sour steam from the steam strippers. The steam strippers serve functions similar to the ammonia strippers, but treat the retort process water. The combined stream is sent to the

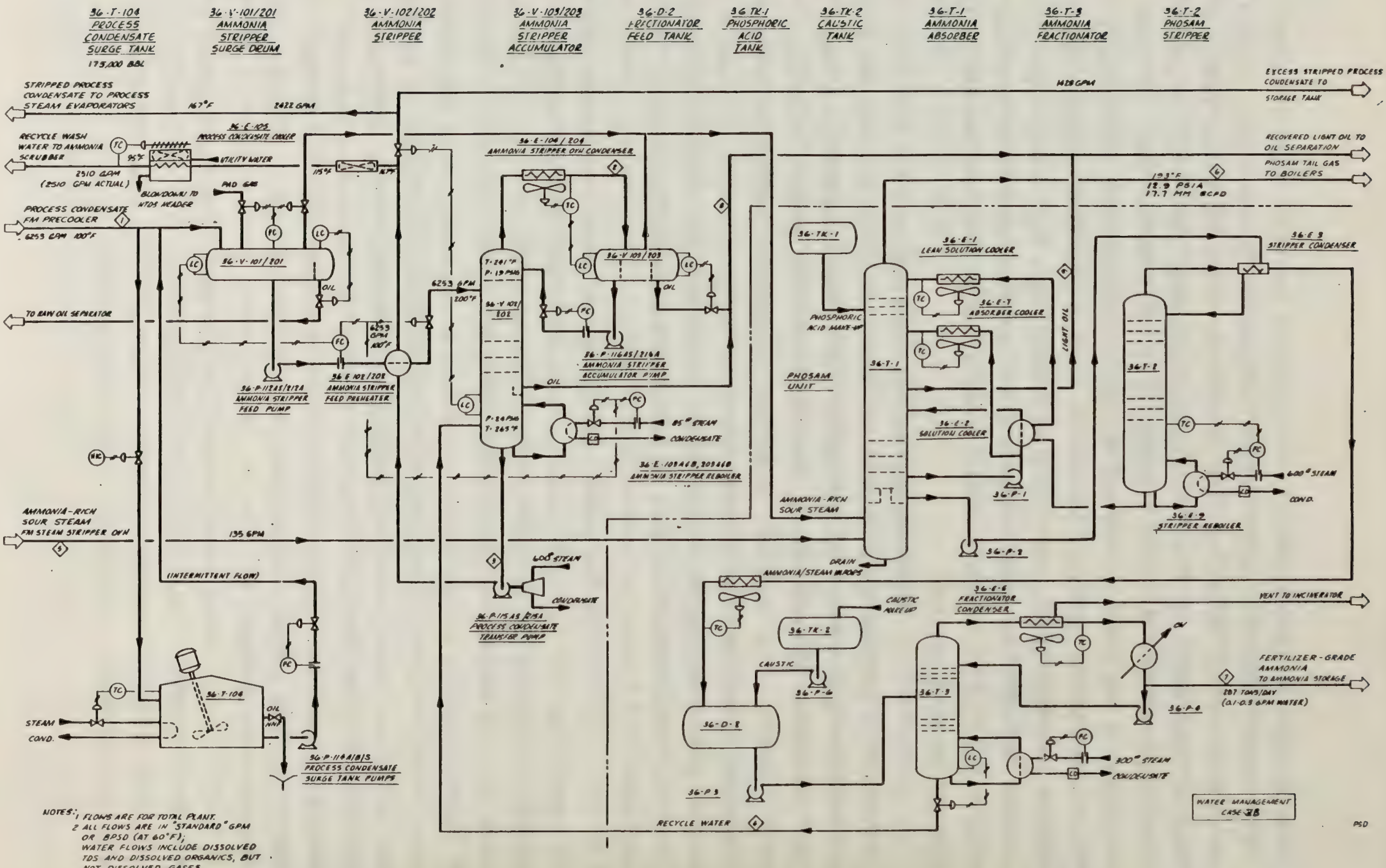

FIGURE II-4.2 PROCESS FLOW DIAGRAM
PROCESS CONDENSATE STRIPPING AND PHOSAM
COMMERCIAL SURFACE PROCESS FACILITIES

TABLE II-4.2 (Revised 11/80)
AMMONIA STRIPPING AND RECOVERY (PHOSAM) MATERIAL BALANCE
(QUANTITIES ARE FOR FIVE OPERATING SURFACE PROCESS LINES AND SEVEN OPERATING LURGI LINES)
(FLOWS ARE FOR TOTAL PLANT)

STREAM / COMPONENT	1 AMMONIA-RICH WATER	2 AMMONIA STRIP-OVHD	3 AMMONIA STRIP BOTTOMS	4 WATER RECYCLE TO AMMONIA STRIP	5 STEAM STRIP OVHD TO PHOSAM UNIT	6 PHOSAM ACID GAS	7 AMMONIA PRODUCT
N_2							
H_2							
NH_3	1,152.4	1,129.	26.1	3.40	306.9	22.1	1,405.4
CO							
C_1							
C_2							
CO_2	698.	697.1	0.3		420.2	1,117.6	
H_2S	6.6	6.5					
C_3=							
C_3							
C4+Light Oils					20.8	20.8	
CS_2							
CH_3SH							
Total M/Hr (dry)	1,857.0	1,832.6	26.4	3.4	747.9	1,160.5	1,405.4
H_2O M/Hr	173,586.	5,052.3	176,553.6	8,064.1	3,747.6	781.5	7.4
Total M/Hr (Wet)	175,443.	6,884.9	176,580.	8,067.5	4,495.5	1,942.	1,412.8
Total Lb/Yr (Wet)	3,175,008.	141,028.	3,178,422.	145,211.6	92,369.3	64,824.	24,025.
MMSCFD (GPM)	(6,253)	62.6	(6,360)	(290)	40.9	17.7	(71.3)

"Phosam W Process" for recovery of high-quality fertilizer-grade anhydrous ammonia.

The Phosam W Process has been selected over competing ammonia recovery systems, based on the close analogy between wet ammonia-rich coke oven gases and the stripper overhead vapors. Both gases contain substantial hydrogen sulfide and volatile organics. The Phosam W Process is highly selective towards ammonia and is basically unaffected by organics in the vapor feed.

In the Phosam W Process, the ammonia-rich sour steam vapors pass into the bottom of an absorber where ammonia is removed by counter-current contact with an ammonia-lean phosphoric acid/ phosphate solution. After selective ammonia removal and moisture reduction, the sour tail gas from the top of the absorber is sent to selected boiler furnaces for burning.

The rich ammonium phosphate solution from the bottom of the absorber is pumped into a stripper/regenerator. In this reboiled stripper, the equilibrium is reversed and aqueous ammonia vapors can be stripped from the rich ammonia solution. The lean phosphoric/phosphate solution is cooled and recycled back to the ammonia absorber in a closed loop. Phosphoric acid makeup needs are relatively small.

Aqueous ammonia vapor from the top of the regenerator passes through a two-stage condenser to form aqueous ammonia enroute to the ammonia fractionator feed tank. A small amount of sodium hydroxide solution is metered into the ammonia fractionator to tie up acid gas trace residuals. The aqueous ammonia liquid is pumped into the ammonia fractionator where distillation at pressure separates a high purity ammonia vapor in the "anhydrous" overhead and a water stream containing less than 0.05 wt percent ammonia in the bottoms. Steam is used to reboil the fractionator tower, providing the necessary vapor flow for stripping and rectifying the ammonia. The overhead, fertilizer-grade anhydrous ammonia is condensed to provide reflux and the anhydrous liquid ammonia product. The ammonia fractionator bottoms are recycled back to the ammonia stripper and combine with the process condensate.

4.4 Boilers And Flue Gas Desulfurization

4.4.1 Description (Figure II-4.3)

The heart of the steam plant is the medium pressure steam boilers arranged in line (as favored by the five parallel offgas

trains). Each medium pressure steam boiler has its own steam drums, forced draft fans, induced draft blowers, FGD absorber and certain FGD slurry circulation auxiliaries. Each pair of steam boilers shares a stack. A boiler and flue gas desulfurization material balance is shown in Table II-4.3.

The steam plant also incorporates three groups of unfired kettle steam generators, five single stage extraction turbogenerators, with aircooled surface condensers, and the main 170 MVA (mega-volt ampere) step-up/ step-down transformer yard and power substation.

The 85 psig steam pressure and flow are controlled by an internal extraction steam valve in the three turbogenerators. The 300 psig steam to supply the kettle evaporators and for water management is produced by topping 600 psig steam in process drivers.

The 240 psig steam level is designed primarily to supply the 1.75 million PPH of process steam to the retorts as air diluent. The water sources for this steam level are stripped process condensate and stripped retort process water, thus effectively closing the process water/steam loop. The process steam pressure represents the minimum needed to meet a 200 psia pressure at the mine collar.

The heating medium to generate 240 psig steam is 300 psig steam. Eighty-five psig steam is used in the excess water evaporators. Kettle type reboilers are used in these steam generating services. Some excess water vapor and some flashed 600 psig blowdown are cooled to provide utility water and makeup water for the cooling tower.

Electrical System

The 600 psig steam system drives five 57.0 megawatt steam extraction turbogenerators. Under winter conditions, these five turbogenerators will be capable of developing 189.8 megawatts of 13.8 KV power to the step-up/step-down transformer/substation facility. Any power in excess of that needed to operate the facility will be put into the grid. However, it is doubtfull that the excess power will ever exceed 10% of the total power generated. Four of the five turbogenerators will be able to pick up almost the entire electrical power generation load allowing one turbogenerator to be tripped out for maintenance. The excess 600 psig steam, under those circumstances, would be let down via the desuperheater as required and any excess power would be exported to the Meeker grid.

The boilers are near maximum unit size and overfiring is limited to perhaps 5-10 percent (due in part to the flue gas desulfurization

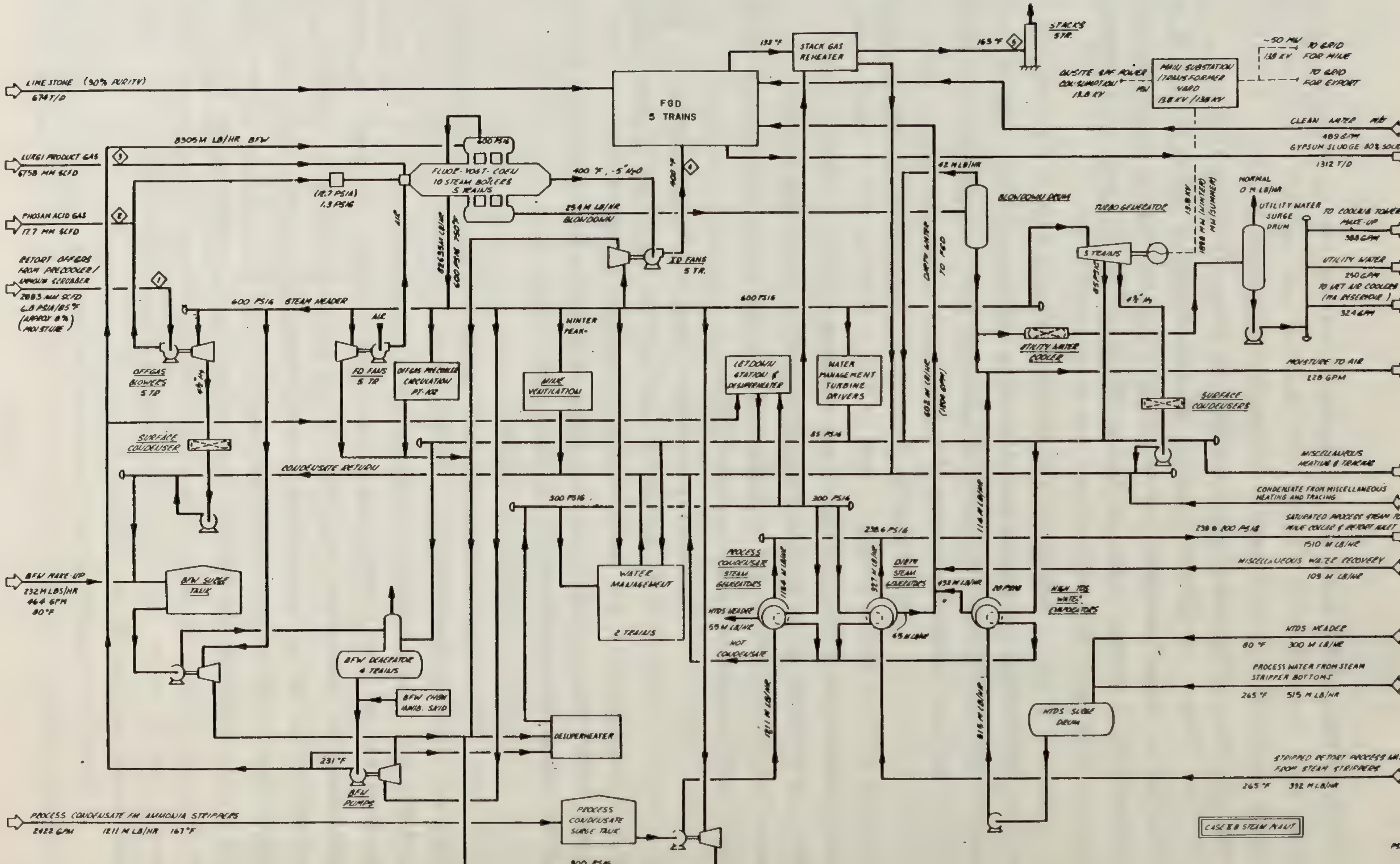

FIGURE II-4.3 PROCESS FLOW DIAGRAM
STEAM PLANT
COMMERCIAL SURFACE PROCESS FACILITIES

TABLE II-4.3

BOILERS AND FLUE GAS DESULFURIZATION MATERIAL BALANCE
(QUANTITIES ARE FOR FIVE OPERATING SURFACE PROCESS PLUS SEVEN OPERATING LURGI LINES)

STREAM COMPONENT	1 COMPRESSED RETORT OFFGAS	2 PHOSAM ACID GAS	3 LURGI PRODUCT GAS	4 BOILER FLUE GAS	5 FGD STACK GAS
H_2	27,519.5		2,336.9		
N_2	177,584.4		230.0	407,707.7	407,707.7
NH_3	579.1	22.1	18.5		
CO	5,124.5		200.3		
C_1	4,715.3		1,112.9		
C_2=	350.8		333.9		
C_2	751.3		400.6		
CO_2	72,430.0	1,117.6	1,868.1	98,446.6	98,446.6
$H_2S(SO_2)$	503.9		5.2	(535.4)	(26.8)
C_3=	233.9		341.3		
C_3	350.8		215.2		
C_4+Light Oils	336.1	20.8	356.1		
COS	14.6				
CS_2	2.9				
CH_3SH	5.9				
O_2				11,550.2	11,550.2
Total, M/Hr (Dry)	290,503.0	1,160.5	7,419.0	518,239.9	517,731.3

TABLE II-4.3
(continued)
BOILERS AND FLUE GAS DESULFURIZATION MATERIAL BALANCE
(QUANTITIES ARE FOR FIVE OPERATING SURFACE PROCESS PLUS SEVEN OPERATING LURGI LINES)

STREAM / COMPONENT	1 COMPRESSED RETORT OFFGAS	2 PHOSAM ACID GAS	3 LURGI PRODUCT GAS	4 BOILER FLUE GAS	5 FGD STACK GAS
H_2O, M/HR	26,458.5	781.5	0	89,247.7	138,078.9
Total, M/Hr (Wet)	316,961.5	1,942.0	7,419.0	607,487.6	655,810.2
Total Pounds, per hour (Wet)	9,019,765	64,822.1	185,616.0	17,757,797	18,604,208
MMSCFD (GPM)	2,883.	17.7	67.58	5,525	5,966
TEMP,°F (PRESSURE, PSIA)	225(12.9)	193(12.9)	95(12.7)	400(11.4)	163(11.4)

temperature limitations and the necessity to retard NO_x formation). The volume of dry MIS offgas in million SCFD will be relatively fixed, with an approximate heating value of 77 Btu/SCF dry or 67-70 Btu/SCF wet.

Each modular boiler has an induced draft fan to provide sufficient draft to balance boiler furnace pressure and sufficient pressure to force the flue gas through the flue gas desulfurization absorbers. In the FGD process, the flue gas is contacted with a basic reagent depending on which of the competing processes is chosen. The SO_2 is reduced to approximately 5% of the inlet SO_2 content by reaction with a basic reagent.

The FGD processes considered: Research-Cottrell Limestone, Davy Saarberg-Holter Lime, and FMC Double Alkali are discussed in detail in Section IV, BACT Assessment. As a result of the assessment, the FMC limestone process was selected as the SO_2 control system.

Each train of an FGD has a stack which takes the effluent of two boilers. A 16 foot diameter, 112 foot high lined stack is proposed for each train. A cone section is to be provided on top of each stack to achieve the exit velocity of about 120 feet per second.

4.5 Above Ground Retorting

4.5.1 Description

The flow diagram (Figure II-4.4) shows the scheme of the surface retorting complex based on the Lurgi Ruhrgas Process. Table II-4.4, shows the product and waste gas component breakdown from the Lurgi.

The Lurgi Ruhrgas Process for the devolatization of fine, granular fuel has been operated commercially with noncoking coals and for oil cracking. Lurgi Ruhrgas employs a recirculating solid heating medium to supply the heat of pyrolysis (retorting). The Lurgi Ruhrgas Process was originally developed with small hot ceramic balls as the heat source. As more experience has been obtained, a switch has been made to fine, granular materials. For coal pyrolysis this can be recirculated coke particles; for oil cracking, the heating medium typically is sized sand ("sandcracker").

In Lurgi Ruhrgas oil shale retorting, the heating medium (at about 950°F) and incoming shale (crushed to minus one-quarter inch), are mixed by screw conveyor/mixers and discharged into a surge hopper/ reactor where the retorting/pyrolysis takes place. After sufficient residence time, the cooler mixture of solids is withdrawn from the bottom of the hopper and charged to a lift pipe/combustor along with preheated air. The carbon on the spent shale is burned off in the lift pipe, heating the solids and air and

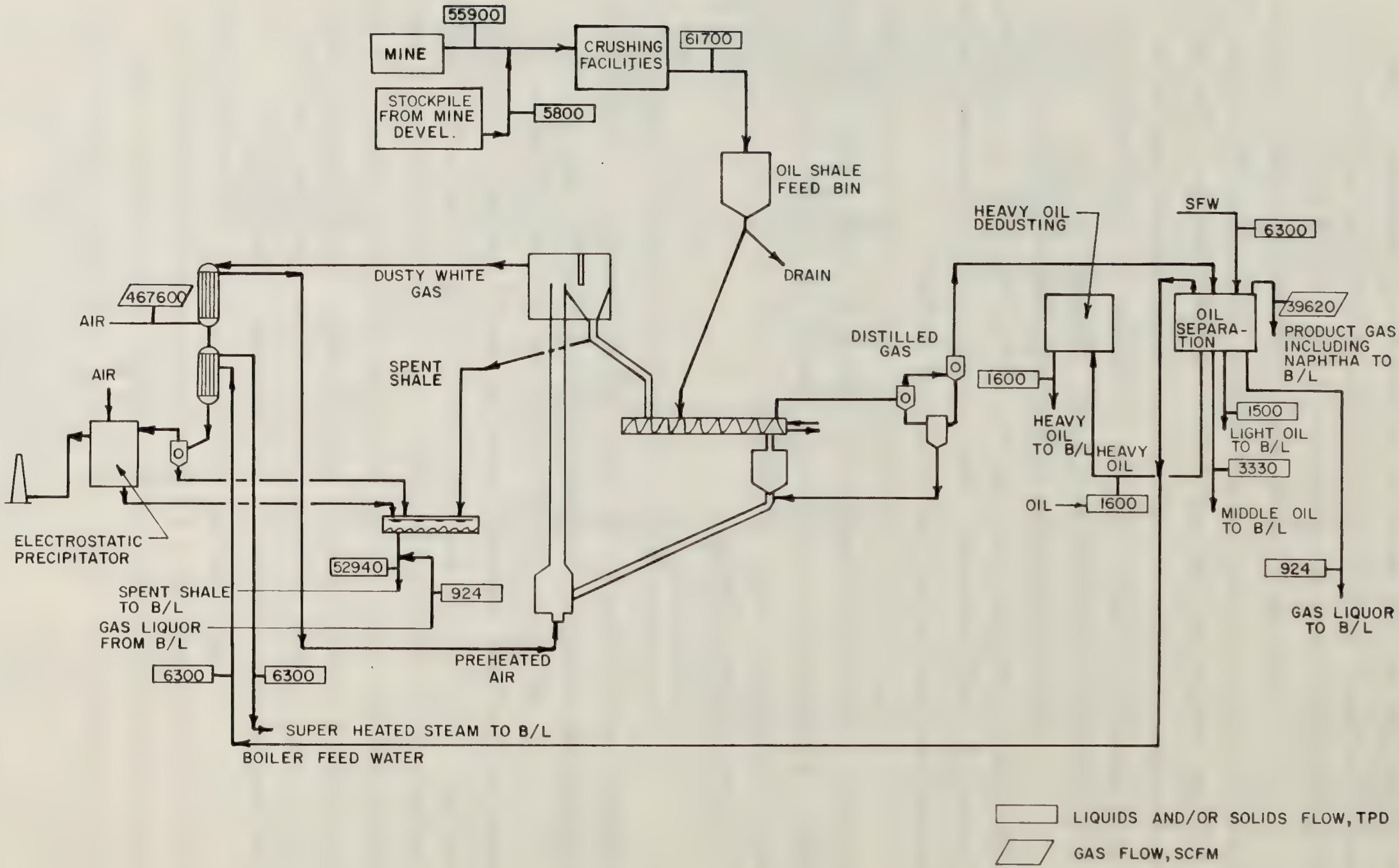

FIGURE II-4.4. BLOCK FLOW DIAGRAM-LURGI PROCESS

TABLE II-4.4

LURGI SURFACE RETORTING MATERIAL BALANCE
(QUANTITIES ARE FOR TOTAL OF SEVEN OPERATING TRAINS)

COMPONENT \ STREAM	LURGI PRODUCT GAS	LURGI WASTE GAS
H_2	2336.9	-
N_2	230.0	66287.0
NH_3	18.5	-
CO	200.3	83.9
C_1	1112.9	-
$C_2^=$	333.9	-
C_2	400.6	-
CO_2	1868.1	14348.0
H_2S (SO_2)	5.2	(1.7)(1.1)
$C_3^=$	341.3	-
C_3	215.2	-
C_4	356.1	-
C_5	-	-
C_6	-	-
C_7	-	-
C_8	-	-
C_9	-	-
C_{10}	-	-
C_{11}	-	-
C_{12}	-	-
C_{13}	-	-
C_{14}	-	-
C_{15}	-	-
C_{16}	-	-
C_{17}	-	-
C_{18}	-	-
C_{19}	-	-
C_{20}^+	-	-
COS	-	-
CS_2	-	-
CH_3SH(O_2)	-	(3178.6)
NO_x	-	8.4
TOTAL M/HR (DRY)	7419.0	83907.6
H_2O M/HR	-	28449.0
TOTAL M/HR (WET)	7419.0	112357.0
POUNDS PER HOUR	185,616.0	-
MMSCFD (GPM)	67.58	1022
TEMP °F (PRESS PSIA)	95 (12.7)	320 (11.4)

giving an exit temperature of around 1250°F. A cyclone at the top of the lift pipe separates very fine solids from the mixture and the rest of the spent shale is recirculated to the mixer and reactor as the heating medium.

As Colorado oil shale is retorted and burned, the spent shale matrix becomes very friable and can break down so that after one or more cycles the spent shale particles will become small enough to be entrained out of the top of the lift pipe cyclone with the hot combustion products. The combined flue gas/fines stream can be treated as a high heat capacity gas. The stream flows through exchanger(s) for air preheat/waste heat steam generation. After further cyclone separation and electrostatic precipitation (as originally developed for cement kilns), the combustion products are discharged to the atmosphere.

The hot pyrolysis products and entrained solids from the reactor vessel pass through a cyclone to a scrubbing system. Sand may be added to the circulating system to provide an adequate recycle to feed shale ratio and act as the heat carrier if the spent shale breaks down too fast.

4.6 Processed Shale Handling and Disposal

4.6.1 Production Quantities

When the individual surface retorts are brought on line and individually reach full production, each retort will produce processed or spent shale at a rate of 6,693 tons per day (TPD). Water and other solid by-products suitable for disposal in the spent shale pile will be mixed with the spent shale in the Spent Shale Handling and Treatment Building prior to being transported to the stockpile. Sketch MSK-13 (Appendix 1.0) identifies the total quantity of materials blended with the processed shale that results in an average yield of 7,507 TPD from each surface retort.

All the shale produced during mine development is assumed to be processed in the suface retorts, which results in approximatly 505 million tons of spent shale. Using an in place compacted density of 100 pounds per cubic foot, this results in a final volume of 374 million cubic yards. The size of the spent shale stockpile, shown on Drawing EM-102, Rev. C (Appendix 4.0) is consistent with this volume.

4.6.2 Disposal Site

Several On-Tract areas were evaluated as the potential location of the spent shale stockpile. Sorghum Gulch (Dwg. EM-102, Rev. C, Appendix 4.0) is the preferred location due to the proximity to treatment

facilities, the small watershed above the proposed site, and the capability of constructing the pile so that processed shale will not extend beyond the ridge line into Stewart Gulch. Owing the quantitiy of spent shale handled, the stockpile will extend above the surrounding terrain and will likely stretch most of the way to the north property boundary and ultimately into Cottonwood Gulch to the west as shown on Drawing EM-102, Rev. C. (Appendix 4.0). However, the selection of Sorghum Gulch minimizes the conveyor/truck haulage distance, which lessens the impact on the environment, and also provides the best arrangement from an economic standpoint.

4.6.3 Site Preparation

The reclamation plan for the spent shale stockpile calls for covering the pile with topsoil as soon as practically possible after the pile reaches its final size in any area. Initial preparation of the disposal site will entail removing topsoil from the area where the spent shale will first be deposited and creating a topsoil stockpile in the Scandard Gulch area as shown on Drawing EM-102, Rev. C (Appendix 4.0). This topsoil pile will remain until the end of the project, at which time it will be used for reclaiming the final portion of the spent shale stockpile in Cottonwood Gulch. As the spent shale stockpile progressed through the life of the project, topsoil will be stripped ahead of the advancing pile and either immediately deposited on completed portions or temporarily stored for reclamation purposes.

4.6.4 Disposal Practices

Processed shale emerges from the retorts as a fine, powdery material (-1/8 inch mesh) with a moisture content from 1 to 2 percent at a temperature of approximately 140°F. A covered conveyor moves the shale to the Spent Shale Handling and Treatment Building where any suitable solid by-products (from the Gas Treatment Facility) and water (for proper compaction and dust control) are blended with the processed shale.

Transfer to the Disposal Pile - A covered belt conveyor, designed to retard moisture loss and prevent fugitive dust generation, carries the blended spent shale overland from the treatment facility to loadout hoppers. The conveyor is built on a strip of land sufficiently wide to provide access (via a service road) for conveyor inspection and maintenance. As the pile grows, both the road and the conveyor will be extended as needed to minimize the movement of trucks and from the advancing face of the pile. If a system failure forces the conveyor to be shutdown, an emergency conveyor is

activated that will dump the blended shale to either storage bins or outside the treatment building. Trucks would then haul this material to the disposal site.

Processed shale will be transferred by 120-ton, diesel-powered trucks from the loadout hoppers to the disposal pile. The trucks will deposit the load while moving in the working area. Graders will shape the material into lifts (under 18 inches thick) prior to compaction by rubber tired compactors and loaded truck traffic.

Shaping the Spent Shale Pile - As shown on Drawing EM-102, Rev. C, (Appendix 4.0), construction of the spent shale pile will begin south of the Surface Processing Plant due to the proximity of the Spent Shale Handling and Treatment Building. During pile development, the conveyor and loadout facility will be periodically moved according to conveyor and haul distance economics. After approximately two years of retorting, pile elevations and the western slope will reach the final configuration. At this time, an overland conveyor belt and the loadout facility will be set up on top of the pile. The pile will then be developed southwards with the western slope and top-of-pile elevation brought to the final configuration. Upon reaching the southern boundary, the pile will be developed eastwards along the length of the entire strip. When the final configuration is reached at the east Sorghum Gulch ridge, pile development will progress northward.

The face of the disposal pile will be built-up using a multiple bench arrangement. Benches are spaced a miximum vertical distance of 100 feet and will be sufficiently wide (100 feet) to provide an adequate turning radius for dump trucks.

Haul roads will provide access from the truck loadout facility to the benches. These roads are at least 100 feet wide to provide safe two-way traffic at normal operating speeds. For greatest climbing and descending efficiency, haul roads will not exceed 8 percent slope. To supress dust on haul roads, a water truck with a sprinkler system will be used. Water will be added in a quantity sufficient to supress dust but not to the point where a muddy or slippery surface is produced.

Dust Control on the Working Face - No more than 50 acres on the working face of the spent shale pile should be exposed at any one time to maintain air quality standards. Dust supression measures will be necessary for the pile due to the size of the face. The inactive area of the working

face will be sprayed with asphaltic emulsion (or equal material) to supress dust. Vehicular traffic will be banned from this area.

Pile Reclamation - Usable soil and overburden material will be removed in front of the advancing spent shale pile. To minimize handling, this material will be stockpiled clear of the filling operations, but relatively close to the pile reclamation area.

At regular intervals during pile development, all exposed surfaces of the pile will be covered with 12 inches of soil and seeded according to an approved Mined Land Reclamation Plan. The final configuration for the pile side slopes consists of a nominal four (horizontal) to one (vertical) with 25-ft. benches cut every 30 feet of elevation. The benches will be cross-sloped to catch any runoff from the sides of the pile.

4.6.5 Water Diversion and Control

A collection ditch and settling pond will be constructed to collect runoff from the shale pile. A ditch will be cut below the toe of the processed shale pile along the east side. The capacity of this ditch will increase as the ditch progresses north toward a catchment dam across the bottom of Sorghum Gulch (Dwg. EM-102, Rev. C, Appendix 4.0). Most of the water collected on the west side of the pile will flow via ditches to another catchment reservoir near Exhaust Shaft No. 2 (Dwg. EM-102, Rev. C, Appendix 4.0). A massive French drain (a covered ditch containing pervious material) will carry this water along the bottom of Sorghum Gulch to the first reservoir at the north edge of the Tract. Water collected here will have sufficient retention time for settling to the required level of solids or, if necessary, this water will be treated. Precipitation falling off-Tract in the Sorghum Gulch watershed will also be collected behind a catchment dam at the southern edge of the pile (Drawing EM-102, Rev. C, Appendix 4.0) and allowed to percolate into the ground. Tests will be conducted to ensure that the watershed will not be contaminated from the shale oil production facility.

5.0 Process Control Reliability

In the analysis of the process control reliability for the prevention of pollutant emissions, we have to look at the surface process facilities as three distinct parts.

A. The Gas Shaft and ducting to the blowers - This system is operated at a negative pressure. Consequently, if there were a leak, it would not emit, but would draw air into the system. This part of the system will be designed such that no leakage or over pressuring will occur.

B. The MIS Surface Process Facility (SPF) - The SPF will process the MIS produced gas. This processing will result in the generation of the following products: Water, condensate (light oil), NH_4, and processed off gas feed to the FGD unit. The design of this facility incorporates higher, longterm operational reliability to reduce emissions. This is achieved by providing 5 parallel SPF trains, each designed for a short-term handling capacity of 25% of the total MIS gas flow and a steady-state design operating capacity of 20% of the flow.

During the initial MIS development utilizing Phase I mining techniques, only four trains will be required to handle the full design flow, with the fifth train acting as a spare. The total oil production in this case will approach 94,000 bpd, about 55,180 from MIS and about 48,300 bpd from AGR. Later, with the achievement of Phase II and Phase III mining techinques, the oil production will increase to 117,275 bpd. This will require operation of all five trains, each handling 20% of the total MIS offgas. MIS oil production will increase to 68,975 bpd during this phase of the mining. Reliability in this phase of operation will be achieved by cross linking the SPF trains by proper valving and by loading four of the five trains to the maximum short-term design capacities when it is necessary to take any one train out of service.

The risk of a total five train outage and consequently, the possibility of any emissions is virtually nonexistent due to the extra short--term capacity designed into each train and the use of steam powered drivers. An entire emergency power generation system will also be provided which will be capable of starting up two trains of boilers, running four forced draft and four induced draft fans,and three boiler feed water pumps. Additionally, the SPF and the FGD systems are operated at a pressure less than atmospheric. However, even though the need for a flare is very remote, a flare will be provided for this system. There is a very remote possibility that the flare could be utilized as frequently as once every five years when the plant is operating at full capacity. This situation would arise in the very unlikely event of a total loss of all control systems. In this event, all inlet air to the MIS retorts would immediately be shut off and an emergency blower to the flare would commence feeding the flare system. This would maintain the retorts at a negative pressure. The maximum flow to the flare would be 2.6 MM scf/hr with a release of 977 MM Btu/hr and approximately 1300 lb/hr of SO_2.

Assuming problems starting up on the emergency power system, we would anticipate that the maximum flare length would be for 5 days. A backup fuel supply will be provided to the flare to insure complete combustion, in the event it would be necessary.

C. Above Ground Retorting (AGR) - At full production, seven Lurgi modules will be operating with the eighth acting as a spare. Product or fuel gas from the AGR modules containing ammonia and sulfur compounds will be fed to the SPF boilers. The flue gas from the boilers is treated for SO_2 removal before discharge to the atmosphere. The AGR gas and liquid separation system will be pressurized and therefore a flare will be provided to discharge emissions should they occur. This flare is designed for 1.8 MM SCF/hr, or a heat release of about 1 billion BTU/hr. At this rate, approximately 200 #/hr of SO_2 will be released. However, a flare of this magnitude would be of a very short duration because of the rapid shutdown capability of the AGR modules and the fact that a spare system will always be available. This flare will also be designed such that it will be smokeless. A backup fuel supply to the flare header will be provided to insure that sufficient fuel will be present for total combustion of all H_2S, sulfur compounds, and hydro-carbons.

6.0 <u>Operating Schedule</u>

As discussed in the preceding section, four of the five SPF trains will be operating at a production rate of about 55,180 bpd during Phase I mining. With overall production increasing to 68,975 bpd during Phase II and III mining, all five trains will be operating on a year-round basis. Also, seven of the eight Lurgi modules will be in service with an overall stream factor of 87.5%, while producing 48,300 bpd. Operations will be on a 24 hour, 7 day week, 365 days-per-year schedule. Sufficient backup of equipment and proper scheduling will allow equipment to be taken off line for turn-around or repair without disrupting the output of product.

III ATMOSPHERIC EMISSIONS

III.

INVENTORY OF ATMOSPHERIC EMISSIONS

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TABLES

III. INVENTORY OF ATMOSPHERIC EMISSIONS ASSESSMENTS:

Fugitive or point source dust emissions are associated with activites associated with surface retorting of raw shale extacted from the underground mine workings. The following types of functions which produce these emissions are as follows:

1. Conveyor and transfer operations
2. Stacking tower storage pile and bottom loadout
3. Secondary and tertiary crushing and screening
4. Bin (silo) loading, storage, and screening
5. Truck loading, haulage, and loadout
6. Stockpile management

Drawing EM-101:

The above functions are integrated and depicted by schematic flowsheet drawings EM-101, which is attached (Appendix 4.0). The drawing identifies each emission point in the process, the shale tonnages being conveyed and processed, the control equipment applications, and a complete emission summary table. The Air Pollution Data table defines the control equipment, efficiency of control, type of pollutant, and emission tonnages.

Drawings EM-102 and EM-103:

The dust emission points identified for the surface retorting process are located on drawings EM-102 and EM-103 (Appendix 4.0). The emission points are depicted on a partial plot plan of the retort process area (EM-103) and a plot plan of the entire facility, which includes the stockpiles (EM-102).

Drawings EM-104, EM-105 and OXY-2

The dust emission points are specifically located with tabulations of Colorado coordinates on the drawings (Appendix 4.0). The emission points are described by their shape and size.

Sketches MSK-1 through MSK-12 (Appendix 1.0) and Drawing EM-107 (Appendix 4.0):

All dust control equipment which is being applied to the emission sources are described schematically or pictorially by Sketches MSK-1 through MSK-12. This includes such items as chemical spray stystems, baghouse dust collection systems, etc. The stacking tower enclosure is shown on Drawing EM-107.

Sketch MSK-13 (Appendix 1.0):

The material balance for handling the raw shale and spent shale is shown on Sketch MSK-13 (Appendix 1.0).

Data Sheets for Performance (Appendix 2.0):

Performance data sheets are provided with each sketch which describes a baghouse, scrubber, or bin vent system. The data sheets define the dust grain loadings, efficiencies, and related design information.

Emission Calculations (Appendix 3.0):

Detailed calculations which are performed to support the predicted emission tonnages are to Appendix 1.0. The references for these computations are mainly from calculation methods described by the U.S. Environmental Protection Agency Region III, Interim Policy Paper on the Air Quality guidelines on the review of surface mining operations pursuant to the Prevention of Significant Deterioration of Air Quality (PSD) regulations, 40 CFR 52.21.

The following drawings and calculations provide the basis and background for the following discussions on the overall emissions for PSD support analysis.

The design PSD production level, i.e. 117,275 barrels per day, will be the basis for the discussion which follows.

1.0 Emission Sources, Controls, and Related Surface Retorting Operations

(Refer to EM-101, 117,275 BPD and 61,730 TPD Raw Shale)

a. The raw shale will be hoisted up the 29' production shaft and transfered onto Conveyors No. 1 and No. 1A at the rate of 26,400 TPD each. Emission points (1) and (2) define the quantity of raw shale dust produced. Two types of controls are used for these emission points, i.e. partially covered conveyors and chemical sprays. The physical description of the conveyor covers are depicted in Sketch MSK-6. THe number and arrangement of spray nozzles are shown on Sketch MSK-1 (Appendix 1.0).

b. The raw shale will be transferred from Conveyors No. 1 and No. 1A to Conveyors No. 2 and No. 2A by a transfer tower. Dust will be generated during the drop of the shale during the transfer. Four insertable baghouses will be arranged on the upper and lower levels of the drop to collect fugitive dust. The baghouses will be manifolded into two stacks, i.e. emission points (3) and (4). During this phase of production, raw shale will be reclaimed from the raw shale stockpile at at rate of 5830 TPD by Conveyors No. 14 to Conveyor No. 2A. An insertable baghouse at the Conveyor No. 14 headframe will be provided to collect dust and then discharged to a stack. This emission is shown as emission point (13). The description of the insertable baghouse is shown on Sketches MSK-2 and MSK-10 (Appendix 1.0), and the associated performance data sheet (Appendix 2.0).

c. Raw shale dust will be generated from an uncovered reclaim area of 15 acres on a raw shale pile. This will result from loading and wind erosion and is defined as emission point (34). Fugitive dust will also be generated by the truck haulage from the raw shale pile to the stacking tower enclosure, i.e. emission point (45). In both cases, water spray is proposed for dust control as described by Sketch MSK-12 (Appendix 1.0).

d. The truck will deposit raw shale to the Conveyor No. 14 hopper. Dust will be generated during this operation as depicted by emission (11). Then the raw shale will be conveyed by a partially covered Conveyor (No.

14) with emission (12) as shown. The physical description of the conveyor cover is shown on Sketch MSK-6 (Appendix 1.0). The emission of fugitive dust will be negligible for these two sources and no further control will be necessary.

e. The raw shale is subsequently transported by Conveyors No. 2 and No. 2A to the stacking towers at a rate of 27,950 and 35,330 TPD each. Emission points (5) and (6) define the quantity of dust produced. The same types of controls apply for these points as emission points (1) and (2). The spray nozzle arrangement is described by Sketch MSK-2 (Appendix 1.0), and the conveyor covers by Sketch MSK-6 (Appendix 1.0).

f. The raw shale is stacked on a conical pile by means of two stacking towers at a rate of 27,950 and 35,330 TPD respectively. The shale will flow downward from the stacking tower through windows into a totally enclosed building (see Drawing EM-107). Four baghouses, two per tower, will collect dust from the tower drop and the traffic inside the stockpile enclosure. The baghouses will also draw air into the enclosures for ventilation. Each baghouse will exhaust to the atmosphere through an I.D. fan at emission points (7), (8), (9), and (10). The equipment is described by MSK-3 and MSK-4 (Appendix 1.0), and the performance data sheets (Appendix 2.0).

g. The total raw shale stockpile bottom loadout rate will be 61,730 TPD, which is equivalent to the sum of Conveyors No. 1 and 2 loading rate and the Conveyor No. 14 reclaim rate from the raw shale stockpile. During the bottom loadout operation each tower will produce one dust generation point each, i.e. (14) and (15). A negligible amount of dust will be generated and contained inside a tunnel below grade. A fan will ventilate the tunnel to the atmosphere. Chemical dust suppression will be used for dust control of both emission points. See Sketch MSK-3 and MSK-4 (Appendix 1.0) for a description of the spray nozzle.

h. Conveyors No. 3 and No. 3A will transport 30,865 TPD each from the bottom loadout at the stockpiles to the secondary and tertiary crushing

facility. As in the case of prior conveyor configurations these will also be partially covered for dust control. Each conveyor is designated as emission point (17) and (18) respectively. The cover for the conveyors is described by sketch MSK-6 (Appendix 1.0).

i. The raw shale is fed to the secondary and tertiary crushing and screening facility at a rate of 61,730 TPD. The dust generated each of these process operations will be controlled by a central baghouse dust collection system. Dust hoods will be strategically located on or near the crushing equipment and the dust collected by a network of ductwork. The baghouse will filter 142,000 CFM of dust laden air which will subsequently be exhausted to the atmosphere as emission point (19). The baghouse dust collection system is described by Sketches MSK-7 and MSK-8 (Appendix 1.0) and the baghouse is described by performance data sheets (Appendix 2.0).

j. Simultaneously as the raw shale is being crushed an elevation change is taking place within a transfer tower. Conveyor No. 4 and No. 4A transport 30,865 TPD each to the transfer tower. Dust is generated during the loadin to these conveyers and the transported to the transfer tower. These emissions are defined by points (20) and (21). The dust will be controlled at the conveyor loadin with water sprays and by partially covered conveyors during transport. The water sprays are described on Sketch MSK-12 (Appendix 1.0), and the conveyor covers are on Sketch MSK-6 (Appendix 1.0).

k. Within the transfer tower the raw shale is loaded on a single conveyor No. 6 to complete the elevation change. A baghouse dust collection system consisting of dust hoods and ductwork controls the dust within the transfer tower. An air volume of 16,000 ACFM will be filtered by the baghouse, which is subsequently exhausted to the atmosphere as emission point (23). The baghouse dust collection system is described by Sketch MSK-9 (Appendix 1.0), and the baghouse is described by performance data sheets (Appendix 2.0).

l. The raw shale is transported from the transfer tower back into the

crushing facility at a rate of 61,730 TPD on Conveyor No 6. At the loading of this conveyor and during transport raw shale dust will be generated. The dust will be controlled at the loadin by water sprays and by partial covers during transport. These emissions are defined by point (22). The water spray nozzle arrangement is described by Sketch MSK-12 (Appendix 1.0), and the conveyor covers by Sketch MSK-6 (Appendix 1.0).

m. After crushing is complete two totally enclosed Conveyors No. 7 and No. 7A transport the finely crushed raw shale at a rate of 30,865 TPD, each to a 30,000 ton fine storage bin. The dust generated by this process is completely contained by the conveyor cover. See MSK-6 (Appendix 1.0) for a description of this cover.

n. The raw shale displaces air volume as it enters the 30,000 ton fine storage bin. The displaced air volume will carry dust with it as it vents from the bin, therefore, a bin vent filter (1200 ACFM bag filter) will be installed on the bin to filter out the dust. This is defined by emission point (26). The bin vent is described by the data sheets (Appendix 2.0).

o. The 30,000 ton fine storage bin unloads to two Conveyors No. 8 and No. 8A. During the drop of the raw shale to the conveyors and the transport to the retort process area dust is generated. The dust is controlled during the initial drop by two insertable baghouse filters (2000 ACMF each). The filtered air is exhausted to the atmosphere as defined by emission points (27) and (28). The insertable baghouse dust collection system is described by Sketch MSK-10 (Appendix 1.0), and the performance data sheets (Appendix 2.0). The dust generated during the conveyor transport is completely contained by the conveyor cover, therefore, there are no dust emissions enroute to the AGR process area. The totally enclosed conveyor is described by Sketch MSK-6 (Appendix 1.0).

p. The raw shale is processed in the surface retorts. The residue, or spent shale, which is approximately 72% (46,850 TPD) of the original raw shale tonnage (61,730 TPD), is transported from the retort, by Conveyor No. 9. The spent shale is powdery and contains only 2% moisture (by weight). Although dust is generated during the transport, it will be completly

contained by the totally enclosed conveyor. The conveyor cover is described by Sketch MSK-6. (Appendix 1.0).

q. Conveyor No. 9 delivers the spent shale to the spent shale handling and disposal area at a rate of 46,850 TPD. Water is added to the spent shale until it reaches a moisture content of approximately 10% by weight. This process brings the material to a workable moisture level for reclamation and stockpiling. Simutaneously, gypsum is being transferred to this facility by Conveyor No. 10 from the gas cleaning process plant. The gypsum is an added ingredient to prepare the spent shale for compaction. Since Conveyor No. 10 is totally enclosed all dust will be contained while in transport to the gypsum storage bins. Sketch MSK-6 describes the totally enclosed conveyor configuration. After the blending and moisturizing process is completed the spent shale is loaded on Conveyor No. 11 for discharge from the facility.

r. While the spent shale is being prepared for stockpiling in the waste and disposal facility, dust is being generated through a series of conveyor belt transfers, bin loadout, blending, etc. The dust will be controlled by pickup hoods, ductwork, and a scrubber unit. A volume of 32,000 CFM will be collected and scrubbed to remove the particulate and exhausted to the atmosphere at emission point (29). The description of the scrubber system is shown in Sketch MSK-11 (Appendix 1.0). The scrubber is also described in the performance data sheets (Appendix 2.0).

s. Initially, Conveyor #11 transports the wetted spent shale to a disposal storage bin from the spent shale handling and disposal area. The conveyor is totally enclosed and, therefore, completely contains any potential dust emissions. Sketch MSK-6 describes the coveyor cover.

t. As the spent shale is loaded into the storage bin by Conveyor No. 11, some dust will be generated in minor quantities as defined by emission point (30). Water will be added to the spent shale to a 10% by weight moisture level. No additional dust control will be needed, since studies have shown that 10% moisture effectively prevents dust generation. The bin will be maintained as empty as possible and used as a loadout to haulage trucks.

u. The spent shale will be transferred from the storage bin by a bottom loadout to 120 ton haulage trucks which will transport it to the spent shale stockpile. During the bottom loadout, no discernable quantities of dust will be generated because of the dampened materials. No control will, therefore, be proposed at this point. Emission point (31) defines the dust produced.

v. The spent shale is transported by haulage trucks at a rate of 52,700 TPD to the spent shale stockpile. Since these roads are on the spent shale stockpile, dust will be generated by the truck movement. Emission point (32) defines the quantities of spent shale dust to be generated. Watering trucks are used to keep the road damp and control the dust. Sketch MSK-12 depicts this type of dust control.

w. The spent shale is placed on a specified area (limited to 50 uncovered acres) at the stockpile, shaped, and compacted. These operations plus wind erosion generate dust as defined by emission point (33). Water sprays will be used for dust control. See Sketch MSK-12 for the description of this control.

x. As the spent shale stockpile grows, Conveyors No. 15 and 16 will be added to reduce truck haulage distance of spent shale. The transfer points of these conveyors will generate dust at emission points 24, 25, 35 and 36. No additional dust control will be provided at these points since the spent shale will contain 10% moisture, which effectively suppresses dust generation. Both conveyors are partially covered, shown as emission points 16 and 37. The description of these conveyors are shown on Sketch MSK-6 (Appendix 1.0).

Several emission points (38, 40, 41, 42, 47, 49, and 50) describe fugitive dust emissions of native soil sources.

2.0 Mine Vents:

Two large ventilation air exhaust shafts, which are indentified as emission points (43) and (44), will exhaust 2.45 million SCFM each to the atmosphere. A tabular summary of the criteria pollutants is depicted on Drawing EM-101. The underground pollutants are generated from two basic operations. First, the diesel driven underground vehicles will produce CO, NO_x, hydrocarbons, SO_2, HCHO (aldehyde), and some particulate. The movement of the vehicles in haulage operations and conveyor operations will contribute to the mine dust entrained by the ventilation air which is subsequently exhausted from the mine. The underground controls for dust will be extensive, e.g. using baghouses, chemical and water sprays, chemical suppression in vehicle areas, and baffles. These control items will maintain dust levels to MSHA respiration tolerances of 2.0 mg/m^3. The mine dust emissions from points (43) and (44) will be based on this tolerance. Secondly, blasting operations will produce dust, NO_x and CO. These pollutants are not continuous, but rather sporatic and reach short duration peak loads while the diesel driven pollutants are produced at a more steady rate. Emission points (43) and (44) are the discharges to the atmosphere through the two 34 meter exhaust stacks.

Mine Vent Emissions. When discussing the mine vent emissions, the concentration parameters should be noted. Mine vent flow is 2.45 million SCFM through each of two 34 foot diameter stacks. Resulting gas velocities are 3760 ft/min. The combined maximum pollutant concentrations are as follows:

	PPM(wt)
CO	93.7
NO_x	118.5
HC	7.9
SO_2	7.1
Particulates	32.0
Aldehyde	1.6

These pollutants are too dilute to employ any SO_2 scrubbing process, CO or HC combustion technique, or baghouse technique on the particulates. Therefore, these emissions are discharged to the atmosphere without further treatment.

3.0 FLUE GAS DESULFURIZATION

Table III-1 shows the expected pollutants entering the atmosphere from the Surface Processing Facility flue gas stacks.

TABLE III - 1

STACK GAS POLLUTANTS[1]

Pollutant	Tons/Day	Tons/Year
NO_x	83.09	30,316.9
SO_2	20.6[2]	7,512.8
CO	Note 3	-
Particulates	0.7	256

1. Total from five Flue Gas Stacks (See Calculations in Appendix 3.0).
2. This is SO_2 remaining after 95 percent Flue Gas Desulfurization.
3. Sufficient excess air is used in the boilers to burn CO to CO_2.

4.0 ABOVE GROUND RETORTING (AGR)

Table III-2 shows the expected pollutants entering the atmosphere from the Above Ground Retort (Lurgi Units) Waste Gas Stack.

TABLE III - 2

LURGI STACK GAS POLLUTANTS[1]

Pollutant	Tons/Day	Tons/Year
NO_x	4.62	1,686.3
SO_2	1.29	470.8
CO	28.2	10,293.0
Particulates	3.3	1,204.5

1. Total from seven Flue Gas Stacks (See Calculations in Appendix 3.0).

5.0 TANK FARM:

Emissions from the shale oil storage tanks are theoretically zero. This is achieved by the following methods: The storage tanks are sealed to prevent any gas or liquid entering or exiting, except within the confines of a closed piping system. Gases which are displaced or evolved from the stored shale oil are collected and fed to a common control system. In this control system, any condensate is pumped back into the storage tanks and noncondensible gases are compressed and discharged into an existing gas stream that is routed into the existing gas treatment facility.

6.0 OTHER FUGITIVE EMISSIONS:

There are diesel powered equipment operations conducted aboveground for the movement of spent shale, raw shale and topsoil, i.e. (8) 120 ton end dump trucks (1200 HP each), (2) D9 dozers, (1) 14 Ft. Blade Grader, and (1) 5000 Gal. water truck. All of the diesel powered equipment will generate criteria pollutants, i.e. SO_2, CO, NO_x and particulate. These pollutants are described on Drawing EM-101 as emission point (51). These vehicles will be maintained to meet applicable emission requirements.

7.0 EMERGENCY EMISSIONS

Redundancy and flexibility has been designed into each portion of the plant to ensure dependability and operational efficiency. Therefore, situations giving rise to emergency considerations have been minimized. The flue gas boilers have supplemental firing with fuel oil such that the onstream reliability of the boilers is maximized to accomplish their primary task as thermal oxidizers.

Two flare systems are provided for The MIS offgas system and the Lurgi retort trains for emergency conditions related to those systems.

No continuous flaring of any stream is envisioned and great redundancy is designed into the overall facility to minimize interruptions giving rise to conditions necessitating flaring.

Tables EM-104, EM-105 and OXY-2 (Appendix 4.0)summarizes Tract C-b emission sources and quantities.

IV BACT
ASSESSMENT

IV.

BACT ASSESSMENT

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IV. BACT ASSESSMENT

1.0 Pollutant Applicability

The assessment of BACT is limited to those pollutants which exceed the de minimus. As set forth in the August 7, 1980 changes to the PSD regulations, the following is a list of the regulated pollutants and their de minimus values:

Pollutant	De minimus Emission Rate	C-b Emissions
Carbon monoxide	100 T/y	11461 T/y
Nitrogen oxides	40 T/y	33215 T/y
Sulfur dioxides	40 T/y	8213 T/y
Particulate matter	25 T/y	3066 T/y
Ozone	40 T/y of V.O.C.	<40 T/y V.O.C.
Lead	0.6 T/y	0.15 T/y
Asbestos	0.007 T/y	0
Beryllium	0.004 T/y	0
Mercury	0.1 T/y	0.003 T/y
Vinyl chloride	1.0 T/y	0
Fluorides	3 T/y	7.8 T/y
Sulfuric acid mist	7 T/y	0
Hydrogen sulfide	10 T/y	0
Total reduced sulfur	10 T/y	0
Reduced sulfur compounds	10 T/y	0

An assessment has been made to determine which of the listed pollutants would be emitted at or above the listed de minimus quantities.

1.1 Carbon monoxide, Hydrocarbon vapors, Reduced and Total Reduced Sulfur Species, Hydrogen Sulfide, and Vinyl Chloride

All the listed substances, except vinyl chloride, are expected to be produced by the retorting and the oil recovery processes. All the listed substances would be subject to combustion and would not be present beyond the boilers, and therefore would not be an emitted pollutant. Vinyl chloride is not present in the raw material and is not synthesized by the process.

1.2 Nitrogen Oxides

Nitrogen oxides will be emitted as products of combustion from the boiler stacks and the Lurgi lift pipe. Approximately 90 tons/day of NO_x is anticipated to be emitted from the facility, which exceeds the 40 tons/year de minimus limit.

1.3 Sulfur Dioxides

Sulfur dioxide is anticipated to be emitted from the plant at the rate of 22.5 tons/day which exceeds the de minimus rate.

1.4 Particulate Matter

Particulate matter is anticipated to be emitted from the facility by both point sources and fugitive sources at a rate of 31.4 ton/day. This rate is in excess of the de minimus level.

1.5 Ozone

Monitoring for ozone is required if the net emission for volatile organic compounds is 40 T/y or more. All V.O.C. material generated in the retorting process, recovery, and storage will be fed to the boilers as fuel. Therefore, any V.O.C. emissions from the facility are anticipated to be small. This is supported by the minimum amount of handling the shale oil will be subject to, the low temperatures and pressures in the processes, and the low vapor pressure of the shale oil. Even though hydrocarbon emissions are anticipated to be below de minimus, BACT will be applied.

1.6 Lead

Analysis of the retort offgas from the Logan Wash facility has not indicated any evidence of lead. The only other possible sources of lead are oil shale fugitive and point source dust emissions. The highest level of lead found in a core of the C-b tract was 65 ppm. Using this level and the estimated emissions of raw and spent shale, an emission of about 0.82 lbs/day or 300 lbs/year could possibly enter the ambient air. Since the de minimus level for lead emission is 1,200 lb/year, we anticipate being well below the de minimus level and no BACT assessment is required.

1.7 Asbestos and Beryllium

Neither asbestos or beryllium have been detected in the Green River oil shale formation. Therefore, there is no reason to expect that there could possibly be an emission of either of these substances as a result of the shale oil operations at Tract C-b.

1.8 Mercury

Mercury has been found to be present in the oil shale at Tract C-b. It ranged from 0.055 to 0.18 ppm by weight. In controlled-state retort tests performed by the Laramie Energy Technical Center, it was demonstrated that up to 70% of the mercury in the oil shale was mobilized. Additionally, Phyllis Fox, of the Lawrence Berkely Laboratories, performed retorting tests using a simulated MIS retort. Ms. Fox's work has shown that mercury is volatilized from the oil shale as the temperature rises, but readily condenses on lower temperature shale, down in the retort. The condensed mercury did not revolatilize until the advancing flame front reached the last part of the retort.

The C-b MIS retorts will be operated such that the offgas leaving the retort will be less than 340°C, therefore eliminating the possibility of any volatilized mercury in the offgas. Mercury that may have condensed in the oil mist, will be removed in the contact condensor, along with the oil.

The AGR (Lurgi) may generate some combined mercury as particulate in the waste gas stream. However, this stream is cooled well below 340°C before it is passed through the ESP. Any volatilized mercury would have condensed and would be carried on the particulates in the waste gas stream. The ESP is designed to remove 99.9% of the particulate loading in the waste gas stream. Therefore, the maximum estimated mercury emission from the AGR offgas stream is 0.016 lb/day, or 5.84 lb/year.

Mercury, in its mineral form, will also be present in fugitive particulates generated from raw and spent shale. This will amount to a maximum of about 0.263 lb/year.

The sum of these emissions, (6.103 lb/year) is well below the de minimus level of 200 lb/year. Therefore, no BACT assessment is required.

1.9 Fluorides

Fluoride is present in the oil shale as CaF_2 and Na_2-(AlF_6). The retorting temperatures of both the AGR and MIS processes are well below the volatilization temperatures for both of the fluoride compounds. Thererfore, no gaseous emissions of fluoride are anticipated.

There will be mineral fluoride emissions that are due to the fluoride content of the particulate emissions. The fluoride mineral composition in these particulates can vary from 600 to 3,400 wt. ppm. Using the maximum concentration and the estimated particulate emission rate, we would

anticipate a maximum mineral fluoride emission rate of about 15,600 lb/year, which is in excess of the de minimus rate of 6,000 lb/year. Since fluoride emissions are related directly to the particulate emission rate, BACT for the particulates will also constitute BACT for control of fluoride emissions.

1.10 Sulfuric Acid Mist

The chemistry of the associated processes are such that no sulfur will be emitted in the form of sulfuric acid mist.

1.11 Summary of the Assessment

The pollutants noted in Table IV-1 are emitted in excess of the de minimus, and, in some cases, by more than one source. Conversly, some individual sources emit more than one pollutant. The SO_2, NO_x and CO emissions are generated by MIS offgas combustion and combustion in the Lurgi lift pipe. The emissions are in excess of the de minimus and BACT is required. Paticulate is emitted from the Lurgi system, material handling systems, and fugitive emission from roads and disposal piles. Particulate emissions are in excess of the de minimus and BACT will be required. Hydrocarbon fugitive emissions will be generated through the handling of hydrocarbon liquids. The quantity of hydrocarbon vapor that could be emitted are anticipated to be less than de minimus, however, BACT will be applied to the emissions.

TABLE IV-1

FACILITY EMISSION ESTIMATES

Constituent	TPD Uncontrolled	TPD Controlled
SO_2	419.2	22.5
NO_x	845.5	90.91
CO	378.9	34.5
TSP		30.4
Fluorides	15,600	7.8
Hydrocarbons	0.38	0.05

2.0 Base Case

The base case is defined as the likely plant configuration if PSD were not applicable to the facility. The major pollutant, which would be regulated by the state of Colorado, is SO_2. The Colorado AQCC, on February 5, 1980, amended their regulation concerning SO_2 emissions from oil shale

facilities to require BACT for the reduction of SO_2. Therefore the base case for SO_2 is BACT. The other pollutants, NO_x, CO, and fluorides, would not be controlled since there are no NSPS standards for oil shale facilities, and the state regulations would not require control. Particulates are regulated by the state on the basis of process weight rate, as described in their regulation #1. Cyclones are generally adequate for meeting process weight rate standards, and hence would be the case for particulates. Fluorides exist as part of the mineral form of the oil shale and is only associated with the particulates. The control of particulates will control the fluorides by default. Storage of hydrocarbons would require compliance with state regulation #7 for storage tank design only, since the facility is not in a hydrocarbon control region, hence the base case is compliance with Colorado regulation #7.

3.0 Selection of a SO_2 Control Strategy

An investigation into alternative control strategies was made. The work was divided into four basic reviews covering SO_2, NO_x, particulates, and CO. The most concentrated effort was directed to SO_2 removal strategies. This study was subdivided into two categories, fuel cleaning and flue gas cleaning. Seven fuel gas cleaning technologies and nine flue gas cleaning technologies were considered. The candidate systems were screened as to their compatibility with the gas stream and general equipment configuration (Table IV-2). Following is a list of the initial candidate systems:

1. Wellman Lord
2. Shell/UOP
3. Diamox
4. Rectisol
5. Benfield
6. Dry scrubbing
7. Citrate
8. Magnesia
9. Soda ash
10. Ammonia
11. ADIP/MDEA amine process
12. DEA
13. Stretford
14. Research-Cottrell Limestone

15. Day Saarberg-Holter Lime
16. FMC Double Alkali

The initial screening narrowed the candidate list to four technologies:

1. FMC Double Alkali
2. Researach-Cottrell Limestone
3. Davy S-H Lime
4. Stretford

The Stretford was further evaluated with a Bevin Stretford added, bringing to a total of five systems that are evaluated in detail. Appendix 5.0 contains the detailed description of the 17 processes considered. The five finalists were then evaluated in terms of the following criteria:

3.1 Sulfur Removal Efficiency Colorado Air Quality Control Regulations provide standards of performance for new stationary sources, including shale oil production facilities. The standard applicable to the Cathedral Bluffs project requires the application of BACT, and further limits total emissions under BACT to 18 tons SO_2 per day, with a requirement to meet an emission limit of 0.3 lbs. SO_2 per daily barrel of production by 1992 or any time prior to that date to boost production beyond that allowed under the 18 ton per day total SO_2 "cap".

On the basis of the foregoing, Cathedral Bluffs was forced to select a very efficient sulfur removal process. Vendors were contacted and were requested to specify the maximum SO_2 removal efficiency which they could guarantee on a continuous basis. Maximum warranted removal efficiency for the three FGD systems examined in detail (i.e., FMC, Research-Cottrell, and Davy S-H) was given as 95 percent based on the gas composition provided (see Table II-1). On further inquiry, if was confirmed that percentage removal is not the important parameter, but rather the exit concentration of the gas following treatment. The range or exit gas concentrations which could be guaranteed on a 24-hour basis, or thirty-day average encompassed 40-50 ppm, with the recognition that meeting the lower limit would require pushing the state of current FGD technology.

The vendors of Stretford fuel gas cleaning equipment will guarantee 99% removal of H_2S. However, the presence of organic sulfur species in the MIS offgas which are not materially affected in the Stretford process, limits the overall SO_2 removal efficiency to 95-96%.

Considering the expected offgas characteristics, vendor willingness to guarantee performance, and physical-chemical limitations of the several process, Cathedral Bluffs established a minimum acceptable removal efficiency criterion of 95%.

3.2 Other Environmental Impacts Some processes, in the course of removing sulfur from the MIS gas, can adversely affect the environment in other ways. An example is the production of a wastewater stream which is extremely difficult or expensive to treat, especially with a goal of zero discharge. Such disadvantages have been properly weighed against any advantages these processes might exhibit in the desulfurization step itself. Solving an air pollution problem by creating a water or solids pollution problem is to be avoided as a matter of policy.

3.3 Commercially Proven Only commercially proven processes have been considered, despite the possibility that an emerging system or technique might someday prove to be superior. Policy dictates that the commercial plant operation must meet established design specifications. Experimenting with possibly superior but commercially unproven technology and equipment would jeopardize the objective.

3.4 Scale-Up Practicality Technology and equipment which have been proven in pilot, bench scale, or semi-commercial operations but which involve uncertainties in scale-up to commercial size are unacceptable. Vessel or other equipment sizes in new and unknown areas of experience are to be avoided due to the risks of inoperability or failure to meet design specifications.

3.5 Operability and Reliability Any plant facility must perform in a reliable and consistant manner. This means that the equipment must demonstrate a high degree of operability, with reasonable endurance, safety, and reliability. Equipment reliability, on a par with typical refinery and chemical plants, is mandatory. Exotic, hard-to-operate, or high maintenance equipment or process systems are unacceptable.

3.6 Energy Efficiency In evaluating alternative processes, due consideration is given to energy efficiency. Some processes inherently require more energy than others in accordance with their chemical and physical schemes. For some treatment processes, the gas must be compressed to extremely high pressures and this would be reflected in a higher energy consumption. The effect of stripping steam on an overall energy balance can also be significant. These criteria severely penalize energy-intensive processes.

Figures IV-1 through IV-10 are brief summaries of the final candidates. Table IV-3 compares the five remaining technologies.

3.7 Process Considerations and Selection

The five processes selected for final consideration have been demonstrated, to appreciable degrees, on commercial scales in process applications approximating the C-b design. Not all of these demonstrations, however, have been at the 95% SO_2 removal level.

The Stretford Process has only been commercially built and operated for gas volumes of 1/4 the volume to be handled per train at C-b. The towers for the Stretford Unit would be 100% larger in diameter and 400% larger in area and capacity than any previously built tower. The scaleup structural problems associated with such large towers are unknown. In addition, the incineration system proposed for recycling spent Stretford solution has not yet been commercially demonstrated.

The Research-Cottrell Limestone Process has had a successful commercial demonstration at Texas Utilities Martin Lake Facility in East Texas, after some initial pH control and gas distribution problems were solved.

A commercial scale FMC Double Alkali Process has been successfully demonstated at several major industrial power plants of Caterpillar Tractor Company, ranging in size from 30 to 250 MW. Consistent SO_2 removals at the 90% level have been demonstrated for this process. However, no commercial installation has yet demonstrated 95% SO_2 removal on a monthly average basis.

The Davey S-H Process has been successfully demonstrated on 125 and 700 MW power plants in West Germany. Additionally, other lime systems have been successfuly used in the United States and abroad. The Davey S-H system does have the distinct advantage over limestone systems of using a clear solution for scrubbing, as opposed to slurry. However, no commercial units have been designed for or operated at the 95% SO_2 removal level.

According to Parson's Engineering, the Bevin sulfur recovery plant (BSRP) has been well demonstrated. The molybdenum catalyst catalytic-reactor design is in operation with Clause Tail Gas Cleaning systems on more than 70 installations. Since Stretford plants are well demonstrated, no major problem is foreseen in putting a Stretford ahead of a Bevin Sulfur Recovery Plant (BSRP).

The bottom portion of Table IV-3 shows cost comparisons of the listed technologies. The comparisons are based on capital installed cost, depreciated by the straight line method over 10 years. This figure is assessed for a three year period in conjunction with the operating and utility cost for three years. The total three year cost was divided by the tonnage of sulfur each process would remove over a three year period at full production capacity to yield dollars per ton of sulfur removed. It can be seen from the last entry of the table that the Davy S-H is the lowest at \$285/ton followed by Stretford at \$307/ton, FMC at \$348/ton, Research-Cottrell at \$396/ton and BSRP at \$702/ton. The Bevin sulfur removal system is considerably more costly than the other systems and will be excluded from the cost analysis. Looking at the remaining four processes, the average cost is \$334/ton, with a standard deviation of \$48.93/ton. Considering the accuracy of these factored cost estimates to be 20%, the costs shown for the four systems are actually equivalent to each other and hence one system should not be favored over the others on a cost basis.

The sulfur removal efficiency is the same for the four processes, which makes them equivalent to each other in that respect also. The BSRP may remove up to 220,418 tons of sulfur over a three year period compared to the four other systems which could each remove 213,669 tons - a difference of 6,749 tons per three years. Comparing the average cost figure of the four systems, \$334/ton to \$702/ton for the BSRP, the Bevin process will cost \$358/ton more. The incremental cost difference for removing the 6,749 tons would be (\$334/ton) (213,669 tons/3 years) - (\$702/ton)(220,418 tons/3 years) = \$83,367,990 (see Table IV 4).

The energy requirements for the five processes are shown on Table IV-5. Davey S-H shows the lowest energy requirement at 53.2×10^6 BTU/day, followed by FMC at 314×10^6 BTU/day, Stretford at 2.91×10^9 BTU/day, Research-Cottrell at 4.28×10^9 BTU/day and BSRP at 23.6×10^9 BTU/day. The FMC energy figure is lower than the other FGDs because the vendor quoted the system based on the generation of calcium sulfite, instead of calcium sulfate. Both Reseach-Cottrell and Davey S-H generate a calcium sulfate product. If the FMC unit were to have an oxidizer section added to convert the calcium sulfite to sulfate, an additonal 4.2×10^9 BTU/day would be required which would raise the FMC energy total to 4.25×10^9 BTU/day. (See Table IV-5).

The byproducts of the sulfur removal processes vary according to the process. Research-Cottrell and Davey S-H processes both generate calcium sulfate. The FMC cost estimate was based on generation of calcium sulfite, a more difficult material to dispose of, unless it is mixed with material which will provide a more stable sludge. The Stretford and BSRP systems generate a sulfur cake which may require land filling. Calcium sulfate or calcium sulfite could be mixed with the spent shale from the surface retort and disposed of. Disposal of these wastes is not anticipated to be a problem.

The cost and energy impacts of the evaluated sulfur removal technologies succeed in clearly eliminating the BSRP. Both the high cost of sulfur removal and the exorbitant energy requirement show the BSRP not to be the proper choice. Also, the incremental costs shown in Table IV-4 demonstrate the impractibility of using BSRP. The cost analysis and control efficiency of the remaining processes show them to be equivalent. The energy analysis, however, shows strong favor toward the Davey S-H process. The apparent energy efficiency of the Davey S-H warrants further analysis. The Davey S-H requires the use of lime as the scrubbing reagent. The regional availability of lime in the quantities required is not firmly established. In the event sufficient lime could not be guaranteed, either a calciner would have to be considered or a limestone scrubber would have to be chosen. If a calciner were chosen, then considerable energy penalty would have to be added to the Davey S-H, making it comparable to the Research-Cottrell and the FMC, with an oxidizer. Also, the operation of a calciner would create an additional emission source to impact the site area. Further, Davey S-H is licensed by a foreign manufacturer, which adds difficulty in procurring the system.

The energy requirements for the Stretford plant make it attractive compared to Research-Cottrell and FMC with an oxidizer. Since the efficiencies of these systems are rated equal, then logically the Stretford would be favored. Unfortunately, there is some uncertainty concerning the organic sulfur fraction in the offgas. The probability of the C-b facility having a much higher organic sulfur fraction in the MIS gas stream than is presently accounted for is very likely. Organic sulfur is not removed very efficiently by Stretford and hence its sulfur removal efficiency would decline. Work is currently in progress to quantify the organic species in the offgas from C-b shale, but will not be completed until late 1981. Until the

new gas analysis results are available, it would not be prudent to specify a Stretford process at this time, especially since the two other processes have been shown to be equivalent in a sulfur removal efficiency which is not subject to changes in MIS gas composition.

The limestone scrubbers, Research-Cottrell and FMC, can operate at the design exit concentration of 44 ppm (vol), even if the organic sulfur fraction should increase in the offgas. Organic sulfur in the gas stream is all oxidized to sulfur dioxide such that the scrubbers never see the variations in the original sulfur species - only SO_2. The efficiency of the scrubbers is controlled by the rate at which the gas is contacted by the limestone reagent. Flexibility will be designed into the facility to allow for changes in SO_2 concentration to maintain the exit concentration specification.

The evaluation of the sulfur removal technologies supports the selection of a lime or limestone flue gas desulfurization process designed for an SO_2 exit concentration not to exceed a 30 day rolling average of 44 ppm (vol).

The Lurgi process generates sulfur dioxide at 20 ppm (vol) as a result of the unique chemistry which takes place in the lift pipe. The majority of the sulfur dioxide initially produced through the combustion process in the lift pipe is reacted with calcium and magnesium oxides formed in the lift pipe, resulting in the formation of calcium and magnesium sulfate. The sulfur removal takes place within the lift pipe without the need for additional equipment or processes. The resultant SO_2 emission of 20 ppm is too dilute for existing sulfur removal processes to provide further significant reduction of sulfur. Therefore, no additional control is needed to achieve BACT for SO_2, with the proposed Lurgi configuration.

4.0 Selecton of NO_x Control Strategy

Evaluation for the control of nitrogen oxides is limited to two approaches. The first is fuel cleaning, by which ammonia is removed from the fuel gas. The second is the combustion of a low BTU gas (65-70 BTU/scf) that produces low flame temperatures (1500-2100°F) and utilizes low excess air rates. Ammonia is removed from the fuel gas by the pre-cooler/ammonia scrubber tower. The scrubber will remove approximately 1120 moles/hr of ammonia from the flue gas. This decrease of ammonia will provide a 91% reduction in NO_x expressed as NO_2. There is no commercially available system known at

TABLE IV-2
EVALUATION OF DESULFURIZATION PROCESSES
Criteria of Unacceptability

	Wellman-Lord	Ammonia	Soda Ash	Citrate	Magnesium Oxide	Shell UPO	Rectisol	Benfield	Diamox	Amine	Dry Scrubbing
RECOVERY BELOW 95%	X		X			X					X
ENVIRONMENTAL IMPACTS OTHER THAN SULFUR			X	X			X	X	X	X	
UNPROVEN COMMERCIALLY			X	X		X			X		
QUESTIONABLE SCALE-UP			X	X					X	X	X
POOR OPERABILITY		X		X	X						
LOW ENERGY EFFICIENCY	X				X		X	X			

TABLE IV-3

SUMMARY OF DESULFURIZATION SCHEMES

	RESEARCH-COTTRELL LIMESTONE SCRUBBING	DAVY S-H PROCESS	FMC DOUBLE ALKALI	STRETFORD PROCESS	ORG. SULFUR CONV-STRETFORD
FEED RATE (SCFM)	3.32×10^6	3.32×10^6	3.32×10^6	1.75×10^6	1.75×10^6
STREAM TREATED	FLUE GAS	FLUE GAS	FLUE GAS	MIS GAS	MIS GAS
SULFUR CONTENT (PPMV)					
SO_2	1,000	1,000	1,000	0	0
H_2S	0	0	0	1,700	1,700
ORGANIC SULFUR	0	0	0	80	80
SULFUR REMOVAL (%)	95	95	95	95	98
SULFUR EMISSIONS (T/D)	11	11	11	11	
NO. OF TRAINS	5	5	5	5	5
NO. OF ABSORBERS/TRAIN	2	8	2	2	2
ABSORBER SIZE (FT)	32 Ø	ROTOPART	30 Ø	33 Ø	33 Ø
UTILITY REQUIREMENTS					
POWER (KW) / day	23,000	12,430	15,600	10,850	57,050
STEAM (LB/HR)	175,620	11,330	0	62,500	125,000
FUEL OIL (BPSD)	0	0	0	228	3,400
INSTRUMENT AIR (SCFM)	340	340	340	375	938
PLANT AIR (SCFM)	340	340	340	375	938
UTILITIES COST					
M $ /DAY	26.80	11.61	14.40	17.21	56.48
B/D SHALE OIL EQUIV.(7)	893	387	480	574	1,882
CHEMICAL REQUIREMENTS					
LIMESTONE (T/D)	587 - 623	0	0	0	0
SODA ASH (T/D)	0	0	36	0	0
LIME (T/D)	0	287 - 310	312	0	0
CATALYST					11,000
BY PRODUCTS					
GYPSUM (T/D) WET	1157 - 1224	1049 - 1118	0	0	0
CALCIUM SULFITE T/D	0	0	1200	0	0
SULFUR (ST/D)	0	0	0	175	185
CAPITAL COST ($MM)					
UNIT COST	82.2	65.9	80.7	98.4	372.3
COMBO-TOWER	0	0	0	8.7	8.7
SLUDGE OXIDATION	0	0	3.0	0	0
TOTAL	82.2	65.9	80.7	98.4	381.0
EVALUATED COST ($MM)					
CAPITAL	82.2	65.9	80.7	98.4	381.0
OPERATING LABOR (3 YRS)	1.1	1.1	1.1	1.1	2.1
MAINTENANCE (3 YRS @ 4%)	9.9	7.9	9.7	11.8	45.7
UTILITIES(1)(3 YRS)	29.3	12.7	15.8	20.9(5)	78.2
CHEMICALS(2)(3 YRS)	17.9	18.0	21.8	2.1	18.4
INSURANCE(3)(3 YRS)	1.8	1.5	1.8	2.2	8.6
BY PRODUCT CREDIT(4)(3 YRS)	0	0	0	(2.1)	
3 YEARS DEPRECIATED CAPITOL (9)	24.66MM	19.77MM	24.21MM	25.92MM	144.3MM
TOTAL	84.66	60.97	74.41	66.12	155.1
($M)/T OF SULFUR REMOVED	396	285	348	307	702

NOTES: (1) POWER @ 3-1/2¢/KWH, STEAM @ $4.60/M LBS, CONDENSATE @ $3.00/M LBS, FUEL OIL @ $15.75/BBL ($2.70/MMBTU), WATER @ $3.00/M GAL

(2) LIMESTONE @ $27/TON, SODA ASH @ $77/TON, LIME @ $55/TON

(3) INSURANCE @ 0.75% OF CAPITAL COST PER YEAR

(4) GYPSUM @ 0, SULFUR @ $11/TON, SULFATE @ 0

(5) INCLUDES ADDITIONAL 6800 KW PENALTY FOR UNIT ΔP AND NO ID FANS

(6) BASED ON 675,000 LBS/HR STEAM @ $4.60/M LBS OR 71.0 MW @ 3-1/2¢/KWH

(7) BASED ON $30/BBL SHALE OIL

(8) HYDROTREATING CATALYST M$

(9) 10 YEAR STRAIGHT LINE DEPRICIATION

TABLE IV - 4

COST COMPARISON

	1) FMC Double Alkali 2) Research-Cottrell 3) Davey S-H 4) Stretford	BSRP	Incremeted BSRP
Tons removed/3 yrs.	213,669	220,418	6,749
Dollars/ton x Tons removed	71,365,446	155,108,147	83,742,701

TABLE IV - 5

ENERGY COMPARISON

BTU/day (equivalent barrels of oil/day)

Research-Cottrell	Davey S-H	FMC	Stretford	BSRP
4.28×10^9	314×10^6	53.2×10^6 additional sludge oxidizer 4.2×10^9	2.91×10^9	23.6×10^9
(713)	(52)	(708)	(485)	(3933)

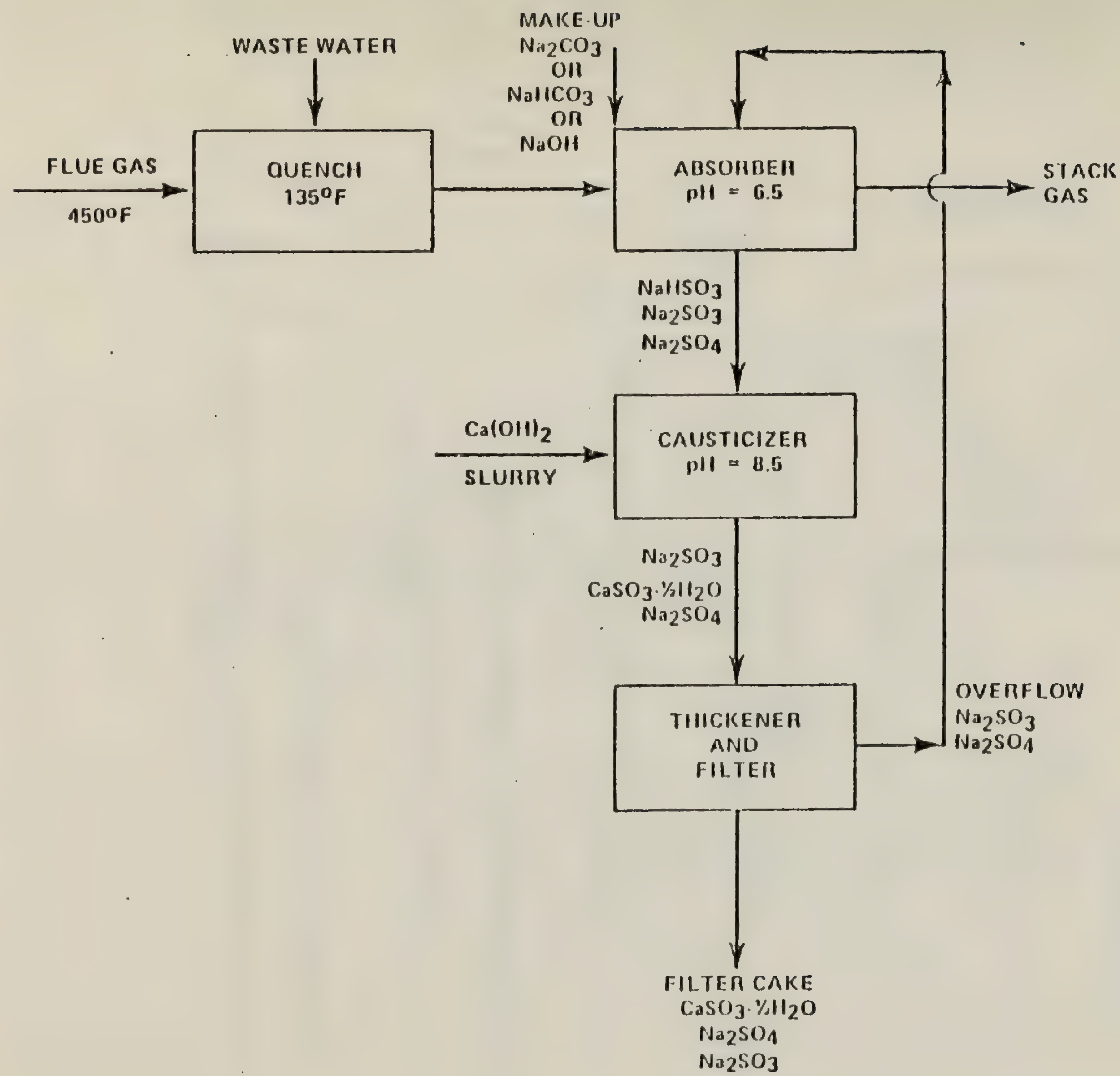

FIGURE IV - 1. DOUBLE ALKALI PROCESS

FIGURE IV-2
DOUBLE ALKALI PROCESS

SO_2 ABSORPTION:

$$Na_2SO_3 + SO_2 + H_2O \dashrightarrow 2NaHSO_3$$
(SODIUM SULFITE) (SODIUM BISULFITE)

$$NaOH + SO_2 \dashrightarrow NaHSO_3$$

ACTIVE SODIUM MAKEUP

$$NaHCO_3 + SO_2 \dashrightarrow NaHSO_3 + CO_2$$
(SODIUM BICARBONATE)

$$Na_2CO_3 + 2SO_2 + H_2O \dashrightarrow 2NaHSO_3 + CO_2$$
(SODA ASH)

SULFATE FORMATION IN SCRUBBING SOLUTION

$$Na_2SO_3 + 1/2O_2 \dashrightarrow Na_2SO_4$$
(SODIUM SULFATE)

REGENERATION OF SCRUBBING LIQUID

$$4NaHSO_3 + 2Ca(OH)_2 \dashrightarrow 2Na_2SO_3 + 2CaSO_3 \cdot 1/2H_2O) + 3H_2O$$
(SLAKED LIME) (CALCIUM SULFITE)

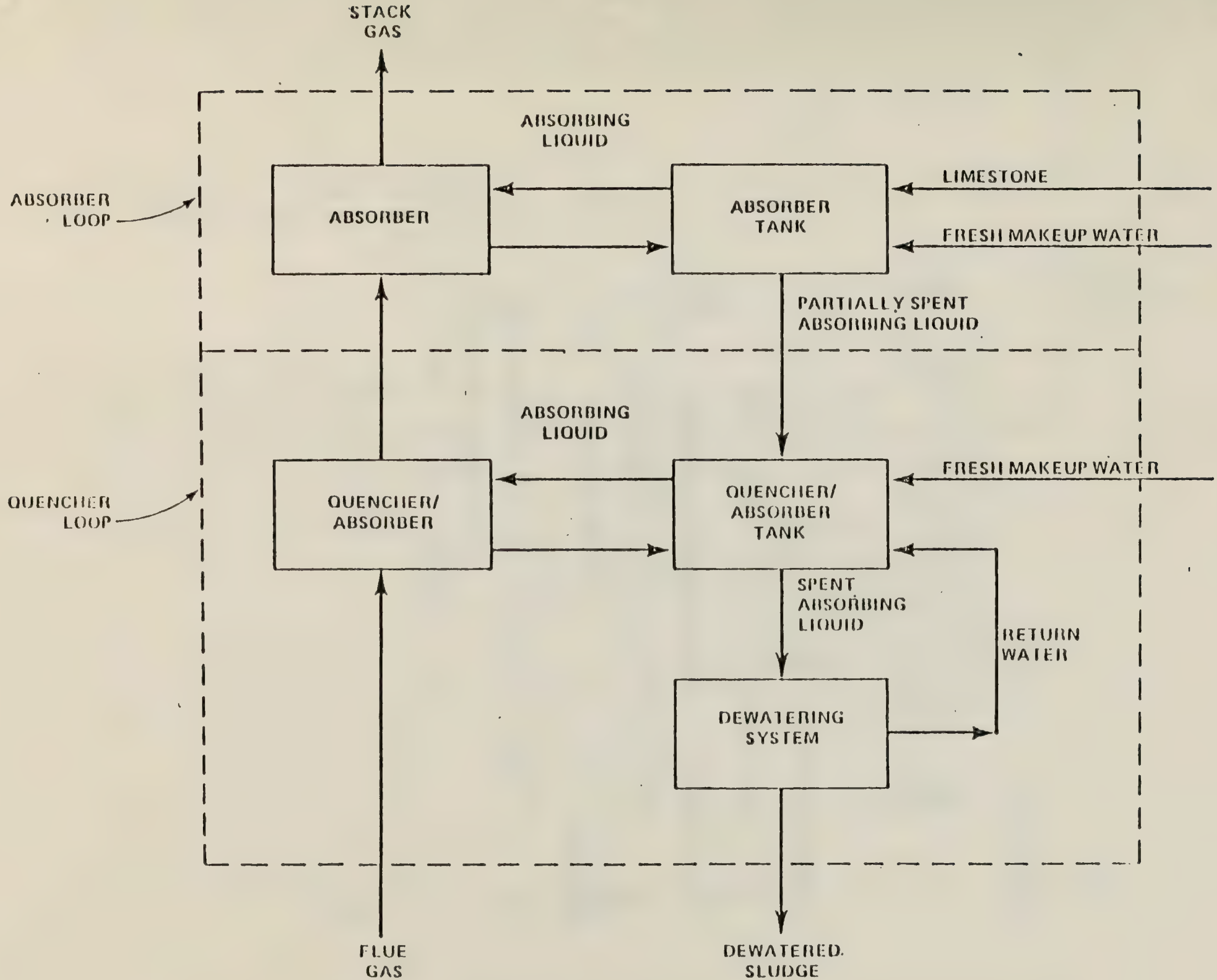

FIGURE IV - 3. RESEARCH - COTTRELL

FIGURE IV-4
RESEARCH - COTTRELL

ABSORPTION:

$$2H_2O + 2SO_2 \rightleftharpoons 2H_2SO_3 \rightleftharpoons 3H^+ + HSO_3^- + SO_3^{-2}$$

$$2H^+ + SO_3^{-2} \rightleftharpoons H_2SO_3$$

SLURRY REACTION AND PRECIPITATION:

$$H_2O + 2CaCO_3 \rightleftharpoons 2Ca^{+2} + HCO_3^- + OH^-$$

(LIMESTONE) (BICARBONATE) (CARBONATE)

$$1/2H_2O + Ca^{+2} + SO_3^{-2} \longrightarrow CaSO_3 \cdot 1/2H_2O$$

(CALCIUM SULFITE)

OXIDATION:

$$1\ 1/2H_2O + CaSO_3 \cdot 1/2H_2O + 1/2O_2 \longrightarrow CaSO_4 \cdot 2H^2O$$

(CALCIUM SULFATE)

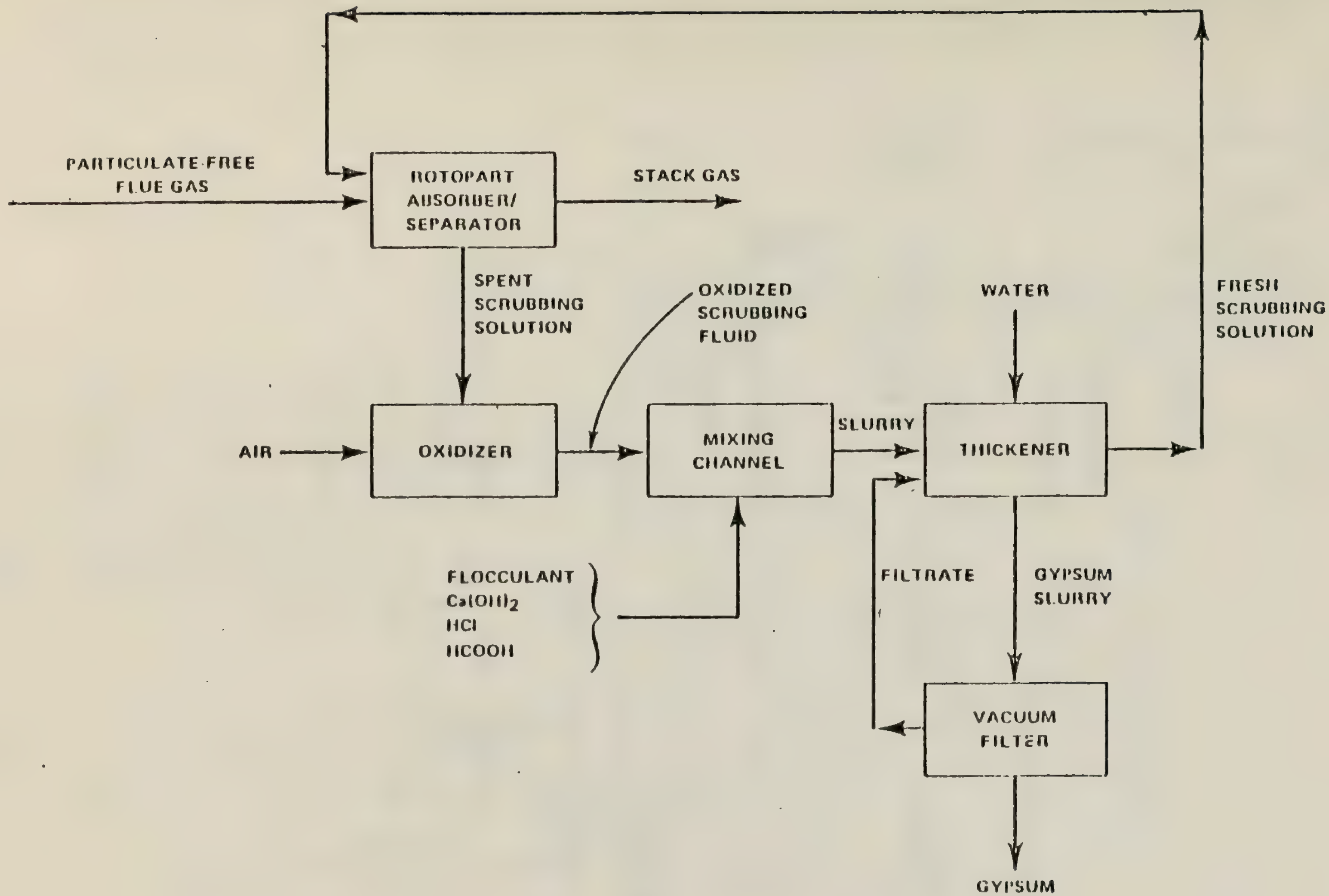

FIGURE IV - 5. DAVY SAARBERG - HOLTER

FIGURE IV-6
DAVY SAARBERG - HOLTER

ABSORPTION:

$$2OH^- + SO_2 \dashrightarrow 2HSO_3^-$$
(BISULFITE)

$$H_2O \rightleftharpoons H^+ + OH^-$$

$$HCOO^- + H^+ \rightleftharpoons HCOOH$$
(FORMATE) (FORMIC ACID)

OXIDATION:

$$Ca^{+2} + 2HSO_3^- + 2OH^- + O_2 \dashrightarrow CaSO_4 \cdot 2H_2O + SO_4^{-2}$$
(GYPSUM)

MIXING SECTION:

$$Ca(OH)_2 \dashrightarrow Ca^{+2} + 2OH^-$$

$$2HCOOH + 2OH^- \dashrightarrow + 2HCOO^- + 2H_2O$$

$$2H^+ + SO_4^- + Ca^{+2} + 2OH^- \dashrightarrow CaSO_4 \cdot 2H_2O$$

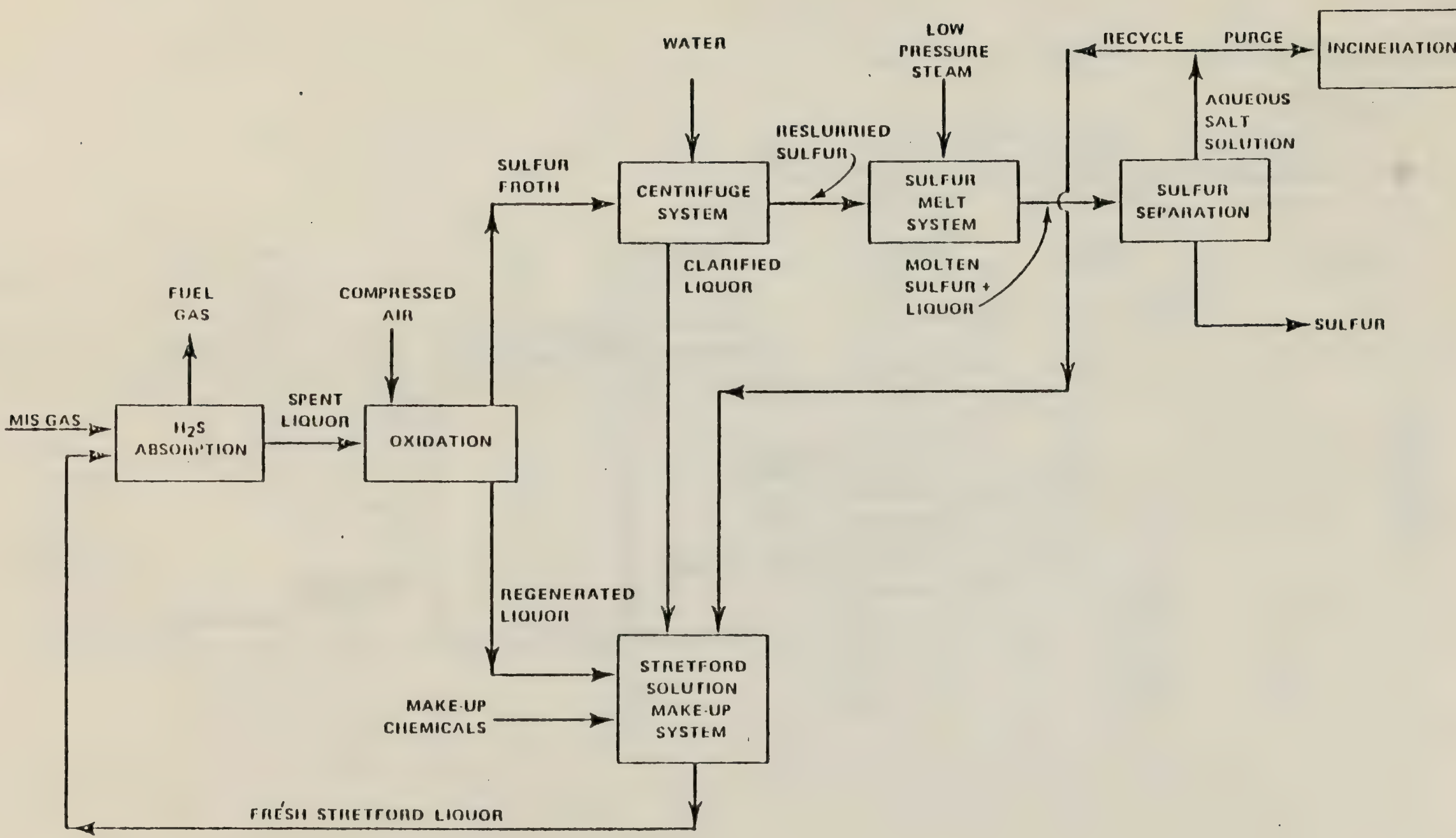

FIGURE IV - 7. STRETFORD

FIGURE IV-8
STRETFORD

ABSORPTION:

$$H_2S \dashrightarrow HS^- + H^+$$

$$HS^- + 2V^5 \dashrightarrow S + H^+ 2V^4$$

OXIDATION:

$$V^{+4} + O_2 \xrightarrow[ADA]{} V^{+5}$$

ADA: ANTHRAQUINONE DISULFONIC ACID

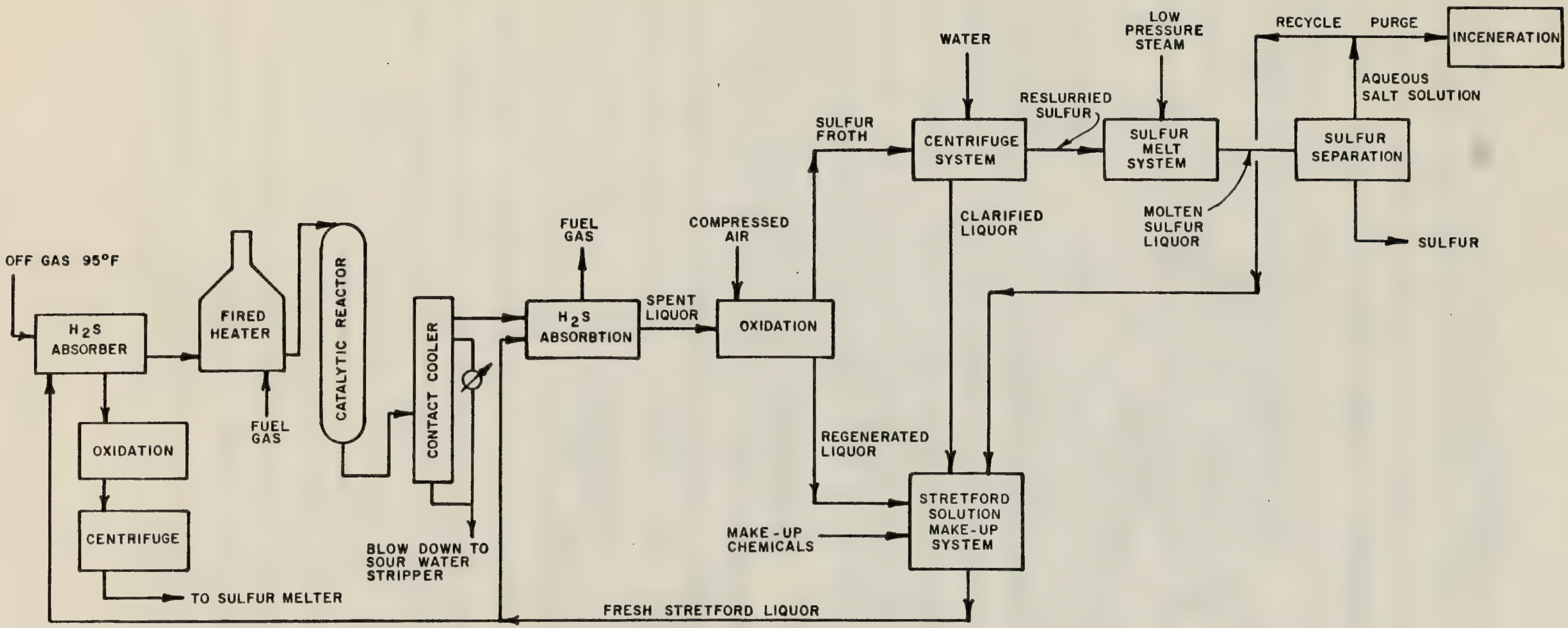

FIGURE IV - 9. STRETFORD - BEVIN STRETFORD

FIGURE IV - 10
STRETFORD - BEVIN STRETFORD

(COS, CS_2, RSH) = Organic (org)

Absorption

$$org + H_2S \dashrightarrow HS^- + H^+ + org$$

$$org + HS^- + 2V^5 \dashrightarrow S\downarrow + H^+ + 2V^{+4} + org$$

Oxidation

$$V^{+4} + O_2 \xrightarrow{ADA} V^{+5}$$

Organic Sulfur Reduction

$$COS + H_2 \dashrightarrow H_2S + CO$$

$$CS_2 + H_2 \dashrightarrow 2H_2S + CH_4$$

$$R\text{-}SH + H_2 \dashrightarrow H_2S + RH$$

Absorption

$$H_2S \dashrightarrow HS^- + H^+$$

$$HS^- + 2V^{+5} \dashrightarrow S\downarrow + H^+ + 2V^{+4}$$

Oxidation

$$V^{+4} + O_2 \xrightarrow{ADA} V^{+5}$$

this time that would provide for more than a 91% reduction, hence the ammonia scrubber combined with combustion of low BTU gas would constitute BACT.

The NO_x emission from the Lurgi process is only 1 ppm (vol) in concentration. There are no known commercial processes that could reduce the NO_x below 1 ppm (vol), therefore BACT for the Lurgi plant is no control.

5.0 Selection of CO Control Stategy

The Lurgi plant generates 82% of the carbon monoxide emitted from the facility through decomposition of carbonates. The remaing 18% is emitted by mine exhaust shafts, surface vehicles, emergency power generators, and the cement batch plant. The CO in the Lurgi flue gas is present at a concentration of approximately 1000 ppm. The heating valve of the flue gas is 0.32 BTU. The only practical method of removing CO is by combustion to CO_2. Due to the low heating valve of the flue gas, an additional 76.1×10^9 BTU or 12,676 barrels of oil would be required to bring the gas to 100 BTU/scf to combust the CO to CO_2. Such a large energy requirement is not practical, considering the small quantity of CO removed, plus the additional pollutants that would be generated from the combustion of the oil. Accordingly, BACT for the Lurgi CO emission is no control.

6.0 Selection of a TSP Control Strategy

The facility has several sources of particulate. Most sources are of a fugitive nature and the remaining are point source emissions. The fugitive emissions are controlled by using water sprays and chemicals as recommended by EPA guide lines for the control of fugitive emissions. Proper management using these guidelines, as described in section II of this application, would constitute BACT. Particulate point sources are in three basic categories. Dust generated through the handling of oil shale by the crushing screening operation, the emission from the Lurgi lift pipe, and the mine vents. Particulate control in the crushing-screening operation is described in Section II and consists of 13 baghouses, and covered conveyors with water chemical spray equipment. The application of these controls is designed to provide the maximum control practical and therefore is BACT.

The flue gas from the Lurgi lift pipe is passed through an electrostatic precipitator (ESP) designed to remove 99.9% of the particulate. The ESP is a design which will remove more particulate than will a baghouse. Baghouses will not capture material less-than 2 microns in size, while an ESP

will. Since the AGR facility will generate the finest material, the ESP is most applicable for this applicaton and is considered BACT.

The mine vent shafts, numbers 1 and 2, emit small concentrations of CO, particulate, NO_x, and SO_2. The concentration of these pollutants are respectively 16 ppm, 6 ppm, 0.2 ppm and 0.0012 gr/SCF. The concentration of these pollutants is sufficiently diluted that no equipment is commercially available which could reduce the emissions effectively. The flow rate on the vents is 3.4×10^6 SCFM. BACT for vent shafts 1 and 2 is considered to be no control.

7.0 Fluoride Control Strategy

Fluoride is contained elementally in the mineral form of the oil shale CaF_2 and $Na_2(AlF_6)$. The processing does not alter the fluoride mineral, hence it is part of the fugitive and point source particulate emission. The applicaton of BACT on particulate sources is also application of BACT on fluoride.

8.0 Hydrocarbon Control Strategy

Hydrocarbon emission from oil shale storage and diesel storage tanks will be conveyed via vapor recovery systems to the boilers. Valves on the tank farm facility will be maintained to minimize leakage. Since vapor recovery and proper maintenance is the best control available, it is considered to be BACT.

V AIR QUALITY ANALYSIS

V.

AIR QUALITY ANALYSIS

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V. Air Quality Analysis

1.0 Summary of Results

The Valley Model was used in an initial screening mode to determine maximum off-tract concentration for SO_2, TSP, CO, and NO_2. CO and NO_2 were not found to be critical conditions, i.e., all concentrations were well below standards off-tract. For all constituents unstable conditions were not critical; for SO_2, TSP, and NO_2 annual conditions were not critical.

Inasmuch as high off-tract SO_2 concentrations were obtained for stable atmospheric stability cases in the initial screening process, the refined AVMSTM rough-terrain model was then utilized. It showed that FGD stacks at 34-m heights and Lurgi stacks at 30-m heights would meet all Federal Class II PSD increments off-tract and Class I increments at the Flattops Wilderness boundary. Because of sufficient plume rise of these buoyant stacks, the Federal increment off-tract was not limiting.

On-tract concentrations of SO_2 were checked from the standpoint of a "workplace environment". That is, the Federal 3-hour secondary standard of 1300 ug/m^3 was required to be met everywhere. It was this standard that was limiting for SO_2.

For particulates, fugitive dust from haul roads and shale piles resulted in high concentrations in the initial screening mode using the Valley Model. In a second iteration a refined model was used which included effects of dry-deposition.

Effects from secondary sources were found to be negligible; those from present permited sources were small.

Table 1 demonstrates compliance with all PSD increments and Table 2 demonstrates compliance with NAAQS.

2.0 Applicable Standards

2.1 National Ambient Air Quality Standards

National Ambient Air Quality Standards (NAAQS) are shown on Table 3 generally representing values not to be exceeded more than once per year with the exception of ozone. Ozone is stated as the number of annual expected exceedances of one-hour-maximum values which must be less than 1.0, averaged over a consecutive 3-year interval. Annual particulate values represent the geometric mean of 24-hour values.

"Ambient" air according to 40 CFR 50.1 (e) is defined as "that portion of the atmosphere, external to buildings, to which the general public

TABLE 1

DEMONSTRATED COMPLIANCE WITH PSD (UG/M^3)

PSD Class	Pollutant	Averaging Time	Maximum Modeling Increment			PSD Limit
			C.B.	Permitted & Secondary Sources	Total	
I	SO_2	Annual	0.06	<0.10	<0.2	2
		24-Hour	<0.01	<0.47	<0.5	5
		3-Hour	<0.01	1.06	1.1	25
	TSP	Annual	0.03	<0.02	<0.1	5
		24-Hour	0.15	<0.13	<0.3	10
II	SO_2	Annual	15.6	0.1	15.7	20
		24-Hour	73	0.0	73	91
		3-Hour	303	0.0	303	512
	TSP	Annual	10	3.5	13.5	19
		24-Hour	29	4.4	33.4	37

Compliance discussion in text:

Class I C.B. - SO_2	Section 5.2.1.1	Pg. V-28
- TSP	6.2.1.1	V-43
II C.B. - SO_2	5.2.1.2	V-28
- TSP	6.2.1.2	V-52
I, II Permitted Sources	7.2.1.1	V-55
I, II Secondary Sources	7.2.1.2	V-63

Table 2

Demonstrated Compliance with NAAQS (ug/m^3)

Pollutant	Averaging Time	Max Modeling Increment (1)	Baseline	Sum*	NAAQS
SO_2	Annual	16	1	17	80
	24-Hour	73	1	74	365
TSP	Annual	14	13	27	75
	24-Hour	34	13	47	260
CO	8-Hour	479	856	1,335	10,000
	1-Hour	858	856	1,714	40,000
NO_2	Annual	74	2	76	100

* Sum = Modeling Increment Plus Baseline
(1) = Includes Permitted and Secondary Sources

Compliance Discussion in Text:

Baseline Values	Section 3.2, Pg.	V-11
SO_2	5.2.2	V-36
TSP	6.2.2	V-52
CO, NO_2	7.1	V-55
PSD Class II Increments	Table 1	V-2

Table 3

NATIONAL PRIMARY AMBIENT AIR QUALITY STANDARDS

Pollutant	Averaging Time	Standard (ug/m^3)
SO_2	Annual	80[1]
	24-Hour Maximum	365
TSP	Annual	75[2]
	24-Hour Maximum	260
	8-Hour Maximum	10,000
	1-Hour Maximum	40,000
NO_2	Annual	100
O_3	1-Hour Maximum	235[3]

(1) Arithmetic Mean of 24-Hour Values

(2) Geometric Mean of 24-Hour Values

(3) Annual Expected Number of Exceedances Must be Less than 1.0 Over 3-Year Consecutive Interval.

has access." For the present application NAAQS and PSD standards are applied at the tract boundary (i.e., off-tract).

2.2 Allowable PSD Increments

Allowable Federal PSD increments are presented on Table 4 for SO_2 and particulates. The C-b Tract is located in a Class II area. Federal increments for Class II apply off-tract. The nearest Class I area is the Flattops Wilderness area approximately 57 km away. Class I increments must be met at the wilderness area boundaries.

2.3 Colorado Standards

Regulations, other than federal, that the facility emissions must comply with, are those of the Colorado Air Quality Control Commission. These regulations control the emission of sulfur dioxide, hydrocarbons and particulates. The Colorado regulations also have set ambient standards for carbon monoxide, particulates, sulfur dioxide, nitrogen oxides and ozone at the identical level to the NAAQS.

The State of Colorado regulates particulate emissions from point sources such as Lurgi by the process weight rate curve for manufacturing processes. Each Lurgi retort would be considered a separate entity according to the state regulations. Since each Lurgi unit would process up to 8,800 tons per day of shale, the regulation would require the use of the following equation to compute the allowable emission rate:

$$E = 17.31\ P^{0.16}$$

where E = allowable emission in pounds/hour and P = process weight rate.

The allowable emission would be:

$$E = 17.31 \left(\frac{8800 \text{ tons/day}}{24 \text{ hours/day}}\right)^{0.16}$$

E = 44.50 pounds/hour allowable emission/retort.

Each retort is allowed 44.5 pounds/hour of particulate emission; however, each retort will only emit 38.9 pounds/hour of particulate. Other sources of particulate such as the crusher screening building comply easily with the process weight rate standard due to the employment of BACT

TABLE 4

AIR QUALITY PSD INCREMENTS FOR SO_2 AND PARTICULATES

STANDARD	MAXIMUM ALLOWABLE INCREMENT (UG/M^3)				
	SO_2			TSP	
	3-HOUR	24-HOUR	ANNUAL	24-HOUR	ANNUAL
PREVENTION OF SIGNIFICANT DETERIORATION (PSD)					
FEDERAL					
CLASS I	25	5	2	10	5
CLASS II	512	91	20	37	19
CLASS III	700	182	40	75	37

control. Fugitive dust emissions are to be controlled as outlined in regulation 1, Section II, Subsection D, through the application of BACT.

On February 5, 1981 the Air Quality Control Commission adopted a resolution amending its regulations one and six, dealing with SO_2 from oil shale facilities. The amendment will be final upon review by the Attorney General and approval by the legislature and is applicable to oil shale production facilities employing MIS and surface retorting technologies in combination such that at least 20% of the ore is processed by the surface retort. The amendment exempts such facilities from compliance with the nonfederal NSPS of 0.3 pounds of SO_2 per barrel of oil produced. The exemption will terminate in 1992 at which time compliance with the NSPS would be required or an extention must be granted by the Commission. BACT control is proposed for SO_2, hence compliance with the state regulation is demonstrated.

The Commission's regulation requires the installation of floating roofs or equivalent on hydrocarbon storage tanks of 40,000 gallons or more. Storage tanks will be constructed using vapor recovery which is better than floating roofs, hence we will comply with the regulation.

3.0 Site Climatology

Site climatology of the C.B. Tract and its vicinity has been extensively documented. A two-year environmental baseline period (November, 1974-October, 1976) was required under the Federal Lease of the U.S. Prototype Oil Shale Leasing Program. Environmental results of this baseline period have been summarized in References 1 and 2. The Environmental Development Monitoring Program which has been followed since baseline (Reference 3) has been approved by the U.S. Department of the Interior (DOI) with concurrence of both the EPA, Region VIII and the State of Colorado. Seventeen data reports have been regularly issued (Reference 4) to the DOI, EPA Region VIII and the State summarizing air quality results every month since baseline. The EPA audited air quality Station 023 quarterly for approximately three years under its Western Energy Audit Program.

3.1 Meteorology

Prevailing winds on-tract are from the south-southwest (SSW). The meteorological network has been adequately described in all the references cited above.

Two sources of meteorological data were utilized for modeling: 1) the 60-meter meteorological tower was used for low-level emission sources with

data covering the two-year baseline span and, 2) upper-air studies from baseline utilizing aircraft and pibal data and that from November, 1977 thru November, 1978 utilizing pibal data were used for high-level releases in unstable conditions. It is to be noted that the upper air studies of the baseline period have shown that only neutral and stable conditions existed above 300-m. Tables summarizing these data are presented in Appendix 11.0 and include:

Table	11.9a thru 11.9f	- Wind Persistence at Specified Stability (Tower Data)
	11.10	- Wind Speed Adjustments to Pasquill-Gifford Stability Classes Obtained from Meteorological T Data
	11.11a. thru 11.11g	- Bivariate Wind Frequency Distributions by Stability Class (Tower Data)
	11.12	- Upper Air Stability Classes (Pibal Data), November 77 - November 78.

Air quality regulations are written such that a standard cannot be exceeded more than once a year. That combination of meteorological conditions resulting in maximum ground-level ambient concentrations is called the "worst case", i.e., that case which is most likely to exceed the standard. It is the second-highest-of-the-highest concentration that would result in exceedances of more than once per year and thus the concentration that governs.

Varying wind speed and direction and atmospheric stability conditions interplay in a complex way so that their combined condition as a "worst case" for ground-level pollutant concentrations most often cannot be prejudged. Thus, one must resort to trial-and-error solutions of "worst-case" meteorological candidates.

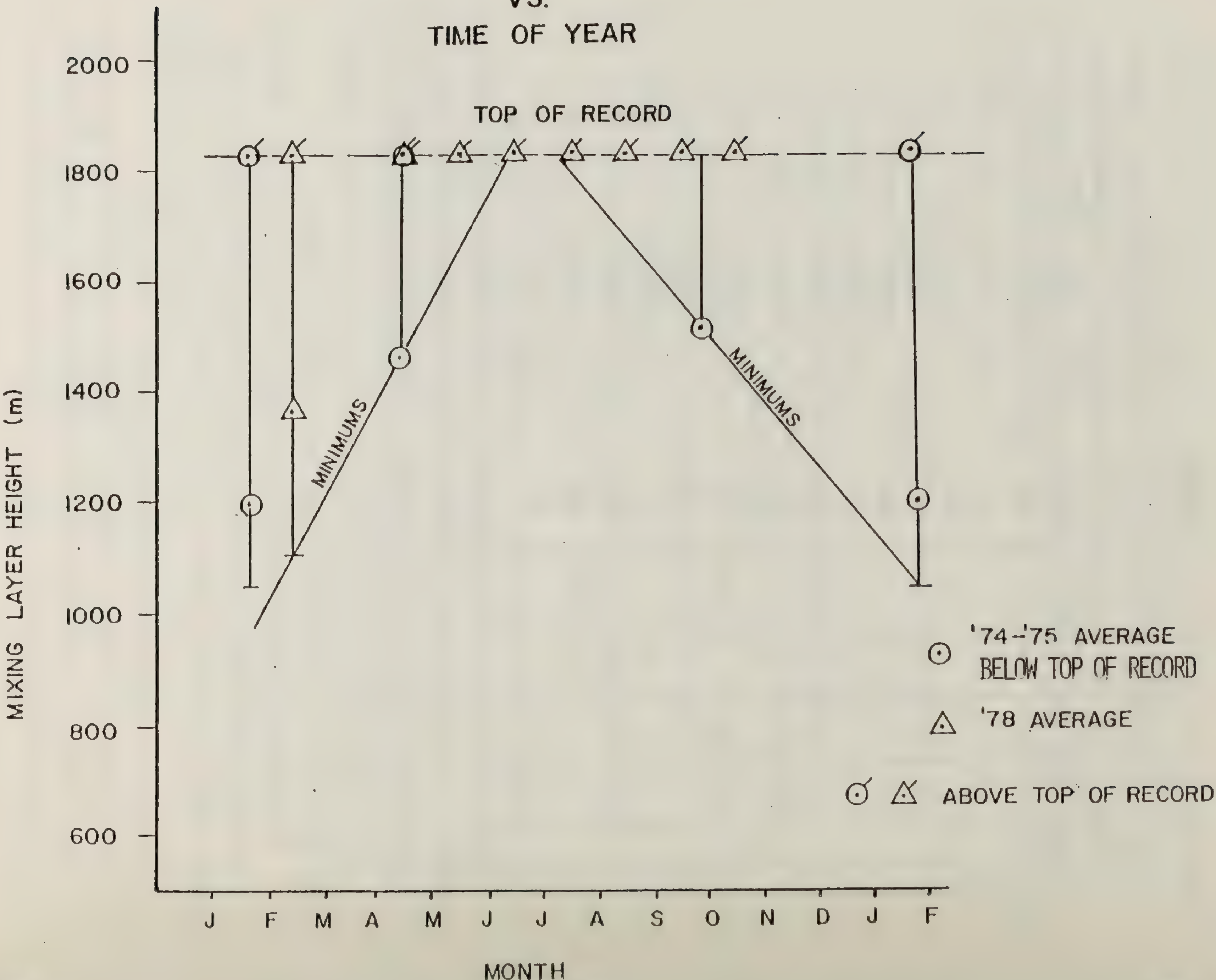
As a result of these investigations that summary of worst-case meteorology candidates which evolved is presented on Table 5. From the above referenced upper-air studies afternoon mixing-layer height vs. time of year has been obtained and is presented in Figure 1. Annual modeling studies

TABLE 5

Summary of Meteorological "Worst Case" Candidates

Case	Stability Case	Persistence (Hrs)	Wind Direction	Wind Speed (mps)	Case Date	Air Temp (^oK)	Bar. Pr. (mb)
1	A	6	WNW	11.3	11/16/77	288	782
2	A	6	All	7.8	5/16/78	284	779
3	A	4	NNE	0.9	12/24/75	271	790
4	A	4	W	2.0	2/05/76	261	781
5	A	6	WNW	1.2	10/27/75	272	788
6	B	6	All	6.8	3/23/78	276	783
7	B	6	SSW	3.9	2/11/76	276	795
8	B	7	SW	4.2	10/18/75	290	793
9	D	25	SSW	10.8	2/07/75	272	783
10	D	25	SSW	12.2	10/26/75	279	782
11	D	5	WNW	1.2	2/14/75	265	779
12	D	11	S	4.9	2/11/75	290	785
13	D	10	SW	7.8	4/13/75	285	784
14	D	4	NNE	1.1	9/20/75	272	780
15	D	5	WNW	1.2	2/14/75	265	779
16	E	10	W	2.1	9/19/76	281	794
17	E	6	SSW	1.0	2/16/75	265	778
18	F	6	SSW	0.9	6/05/75	288	789
19	F	6	SSW	2.2	5/28/76	287	787

FIGURE 1
AFTERNOON MIXING LAYER HEIGHT
VS.
TIME OF YEAR



utilized the bivariate frequency distributions of Table 11.11, referenced above.

To summarize the cases examined, these are (from Table 5):

For SO_2 - Cases 1, 2, 6, 9, 13, 15-19, Annual

For TSP - Cases 3-5, 7, 8, 12-15, 17, 18, Annual

For CO - Cases 15, 17, 18

For NO_x - Annual

3.2 Air Quality

From the references cited above annual mean concentrations have been obtained for the criteria pollutants each year from 1975 thru 1980. These averages are presented on Table 6. On the basis of this extensive data set, baseline values utilized for demonstration with NAAQS are as follows:

SO_2 - 1 ug/m^3

TSP - 13

NO_2 - 2

CO - 856

4.0 Model Description and Utilization

4.1 Screening Technique

The EPA Valley Model is widely used in rough-terrain air diffusion modeling studies. It is both inexpensive and convenient to use for both short-term and annual non-reactive-pollutant studies. Plotted outputs of ground-level concentrations are obtained for each of the multiple emission sources as well as their sum. Its shortcomings stem from the facts that it yields overly conservative unrealistically-high results for stable atmospheric cases and for those cases where emission sources are characterized by a wide variation in mass distribution. For this latter case a dry-deposition (i.e., "settling") term would be a realistic improvement (and is readily incorporated).

Therefore the modeling approach taken was to use the EPA Valley Model in an initial screening mode to both identify those meteorological conditions which resulted in high ground-level concentrations of the pollutant plume and to dismiss from further study those conditions for which concentrations were low. Actual meteorology including wind persistence was used. Then those few conditions resulting in high concentrations were subjected to further analysis using more refined models. For SO_2 a site-specific rough terrain model developed by AeroVironment and called AVMSTM was utilized. For

Table 6

ANNUAL MEAN CONCENTRATIONS FOR NAAQS CRITERIA POLLUTANTS AT STATION AB23***

CONSTITUENT	1975	1976	1977	1978	1979	1980
SO_2	0.7	0.7	0.3	1.3	0.4	1.0
NO_2	1.3	4.2*	0.9	0.0	2.0	1.0
Particulate**	10.7	7.4	8.3	9.1	13.3	8.3
CO	623	856	335	311	208	67
O_3	66.4	62.0	79.7	81.1	77.1	75.3

* <50% Data

** Geometric Mean

*** Instrument Specifications are given on pp. A-173 and A-179 of Volume 24 of the 1979 C.B. Annual Report. Instruments used are as follows:

Item	Instrument	Span of Use
SO_2, H_2S	Meloy SA-185-2	Nov 74-Mar 77
	Meloy SA-185-2A	Apr 77-Present
CO	Bendix 8500 Chromatograph	Nov 74-Aug 78
	Beckman Model 866	Sep 78-Present
NO_x	Meloy NA-520-2 Chemiluminescence	Nov 74-Dec 77
	Monitor Labs Model 8440E NO_x Analyzer	Jan 78-Present
03	Meloy OA-350-2 Ozone Analyzer	Nov 74-Mar 79
	Meloy OA-350-2R Ozone Analyzer	Apr 79-Present

TSP a dry-deposition term (using Stokes settling law) was included in the Gaussian diffusion equation of the Valley Model to readily accommodate the wide range of particle sizes characterized by the major emission sources. The EPA has been informed of this refinement.

4.2 EPA Valley Model

The EPA-developed Valley Model has been documented previously. This so-called Gaussian plume formulation calculates 24-hour average ground-level pollutant concentrations in each wind sector for specified meteorological conditions and Pasquill-Gifford stability class. Other short-term concentrations such as the 3-hour SO_2 and the 1- and 8-hour concentrations for CO are obtained from the so-called power law. For example for a 3-hour averaging time:

$$\chi_{3\text{-hr}} = \chi_{24\text{-hr}} \left(\frac{24\text{-hr}}{3\text{-hr}}\right)^{0.44}$$

where: $\chi_{24\text{-hr}}$ = 24-hr concentration from the Valley Model

$\chi_{3\text{-hr}}$ = 3-hr concentration (calculated)

Annual concentrations are calculated from an annual bivariate wind frequency distribution by Pasquill-Gifford atmospheric stability class as obtained from site measurements as described in Section 3.1.

For both short-term and annual averages, ground level concentrations are calculated for the selected scale (called "grid" in the model) at each imaginary receptor site in the model. Receptors are located approximately in seven concentric rings along rays of the 16 compass wind directions with ring one being the innermost. Distances are shown on Table 7 for model scales of 50, 100, 200, 400, and 2,000 grid. The tract boundary is shown between appropriate receptors as a horizontal line along each ray (i.e., compass heading).

4.3 Rough Terrain Model AVMSTM

4.3.1 <u>Tracer Study</u>

In September, 1978 tracer studies were conducted at the C-b Tract as part of the model validation experiment. That is, the AVMSTM is

TABLE 7

EPA VALLEY MODEL RECEPTOR DISTANCE FROM ORIGIN (KM) AS A FUNCTION OF GRID SIZE

Grid	Ring	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
50	1	.42	.37	.35	.44	.40	.44	.35	.37	.42	.27	.49	.44	.40	.44	.49	.27
	2	.75	.73	.84	.86	.80	.86	.84	.73	.75	.74	.84	.87	.80	.87	.84	.74
	3	1.17	1.18	1.19	1.26	1.20	1.25	1.19	1.17	1.17	1.18	1.20	1.26	1.20	1.26	1.19	1.17
	4	1.58	1.64	1.64	1.52	1.60	1.52	1.64	1.64	1.58	1.65	1.65	1.52	1.60	1.52	1.64	1.64
	5	2.00	2.00	1.99	1.95	2.00	1.95	1.99	1.98	2.00	1.99	2.00	1.96	2.00	1.96	1.99	1.99
	6	2.42	2.35	2.34	2.34	2.40	2.34	2.34	2.35	2.42	2.35	2.35	2.34	2.40	2.34	2.35	2.35
	7	2.83	2.71	2.70	2.82	2.80	2.82	2.70	2.71	2.83	2.73	2.71	2.82	2.80	2.82	2.70	2.72
100	1	.84	.74	.70	.88	.80	.88	.70	.74	.84	.54	.98	.88	.80	.88	.98	.54
	2	1.50	1.46	1.68	1.72	1.60	1.72	1.68	1.46	1.50	1.48	1.68	1.74	1.60	1.74	1.68	1.48
	3	2.34	2.36	2.38	2.52	2.40	2.50	2.38	2.34	2.34	2.36	2.40	2.52	2.40	2.52	2.38	2.34
	4	3.16	3.28	3.28	3.04	3.20	3.04	3.28	3.28	3.15	3.30	3.30	3.04	3.20	3.04	3.28	3.26
	5	4.00	4.00	3.98	3.90	4.00	3.90	3.98	3.96	4.00	3.98	4.00	3.92	4.00	3.92	3.98	3.98
	6	4.84	4.70	4.68	4.68	4.80	4.68	4.68	4.70	4.84	4.70	4.70	4.68	4.80	4.68	4.70	4.70
	7	5.66	5.42	5.40	5.64	5.60	5.64	5.40	5.42	5.66	5.46	5.42	5.64	5.75	5.65	5.40	5.44
200	1	1.67	1.47	1.40	1.74	1.60	1.74	1.40	1.47	1.67	1.08	1.96	1.74	1.60	1.74	1.94	1.06
	2	3.00	2.92	3.34	3.44	3.20	3.44	3.34	2.92	3.00	2.94	3.36	3.48	3.20	3.48	3.36	2.94
	3	4.66	4.70	4.76	5.04	4.80	5.00	4.76	4.68	4.66	4.72	4.80	5.04	4.80	5.02	4.76	4.68
	4	6.33	6.54	6.54	6.06	6.40	6.06	6.54	6.54	6.27	6.58	6.60	6.08	6.40	6.08	6.56	6.54
	5	8.00	8.00	7.96	7.80	8.00	7.80	7.96	7.92	8.00	7.96	8.00	7.84	8.00	7.82	7.96	7.94
	6	9.67	9.40	9.36	9.36	9.60	9.34	9.36	9.40	9.67	9.40	9.40	9.36	9.60	9.34	9.40	9.40
	7	11.33	10.84	10.80	11.26	11.20	11.26	10.80	10.84	11.33	10.90	10.84	11.28	11.80	11.28	10.80	10.80
400	1	3.33	2.93	2.80	3.48	3.20	3.48	2.80	2.93	3.33	2.16	3.92	3.48	3.20	3.48	3.88	2.1[illegible]
	2	6.00	5.44	6.68	6.88	6.40	6.88	6.68	5.44	6.00	5.88	6.72	6.96	6.40	5.88	6.72	5.8[illegible]
	3	9.32	9.40	9.52	10.08	9.60	10.00	9.52	9.36	9.32	9.44	9.60	10.08	9.60	10.04	9.52	9.3[illegible]
	4	12.45	13.08	13.08	12.12	12.80	12.12	13.08	13.08	12.45	13.16	13.20	12.16	12.80	12.16	13.12	13.0[illegible]
	5	16.00	16.00	15.92	15.60	16.00	15.60	15.92	15.84	16.00	15.92	16.00	15.68	16.00	15.64	15.92	15.8[illegible]
	6	19.33	18.80	18.72	18.72	19.20	18.68	18.72	18.80	19.33	18.80	18.80	18.72	19.20	18.68	18.80	18.80
	7	22.67	21.68	21.60	22.52	22.40	22.52	21.60	21.68	22.67	21.80	21.68	22.56	22.40	22.56	21.60	21.76
2000	1	16.7	14.7	14.0	17.4	16.0	17.4	14.0	14.7	16.7	10.8	19.6	17.4	16.0	17.4	19.4	10.6
	2	30.0	29.2	33.4	34.4	32.0	34.4	33.4	29.2	30.0	29.4	33.6	34.8	32.0	34.8	33.6	29.4
	3	46.6	47.0	47.6	50.4	48.0	50.0	47.6	46.8	46.6	47.2	48.0	50.4	48.0	50.2	47.6	46.[illegible]
	4	63.3	65.4	65.4	60.6	64.0	60.6	65.4	65.4	62.7	65.8	66.0	60.8	64.0	60.8	65.6	65.4
	5	80.0	80.0	79.6	78.0	80.0	78.0	79.6	79.2	80.0	79.6	80.0	78.4	80.0	78.2	79.6	79.[illegible]
	6	96.7	94.0	93.6	93.6	96.0	93.4	93.6	94.0	96.7	94.0	94.0	93.6	96.0	93.4	94.0	94.0
	7	113.3	108.4	108.0	112.6	112.0	112.6	108.0	108.4	113.3	109.0	108.4	112.8	118.0	112.8	108.0	108.8

HORIZONTAL LINES FOR EACH GRID SIZE REPRESENT THE TRACT BOUNDARY

a site-specific model which therefore has to be validated for the applicable site. Tracer gas (SF_6) released at 100-m above the surface was sampled at 23 fixed locations to determine plume location as a time history. In addition 61 grab samples were taken. Wind speed, turbulence and direction measurements were made on the 60-m tower, and wind speed and direction were measured at 8 other locations; a tethersonde was used to obtain the vertical distribution of wind and an acoustic radar was utilized to obtain atmospheric stability and inversion conditions. This report (Reference 7) is presented in its entirety in Appendix 6.

4.3.2 Model Validation

Validation of the AeroVironment rough terrain air-diffusion model called AVMSTM was undertaken in November, 1978. This model treats the wind field, plume transport and turbulence in complex terrain. Results are presented in Reference 8 in Appendix 7. The correlation coefficient between observed and predicted SF_6 concentrations at 23 sites was 0.91. The slope of the linear regression between observed and predicted values of 0.87 indicated that, on the average, the model overpredicts by 13%. Temporal trend analyses of predicted vs. observed concentrations at peak-concentration sites are shown in the Appendix, indicating good agreement.

A presentation was made in March, 1980 by AeroVironment to the EPA Region VIII on model validation results. As a result of this meeting, the EPA requested additional information in four areas: 1) a regression analysis of model predictions vs. actual measurements using a data set that excludes near-zero concentrations; 2) a standard error of the estimate of the model predictions; 3) a description of the range of concentrations that the model overpredicts and the range of concentrations that the model underpredicts; and 4) a comparison of observed and predicted concentrations at Station 20 (the Collins Overlook location for which the Valley Model predicts high concentrations under stable atmospheric conditions). This informational response has been furnished to EPA (Reference 9) and is as follows:

(1) A regression plot of observed versus predicted concentrations was obtained using a data set that excludes all data pairs that have both values of less than or equal to 0.05 ug/m^3. One-hundred-and-ten pairs of data were eliminated from the original data set. The regression plot is shown in Figure 2. The correlation coefficient is 0.90. The intercept is 0.00 ug/m^3 and the slope is 0.87.

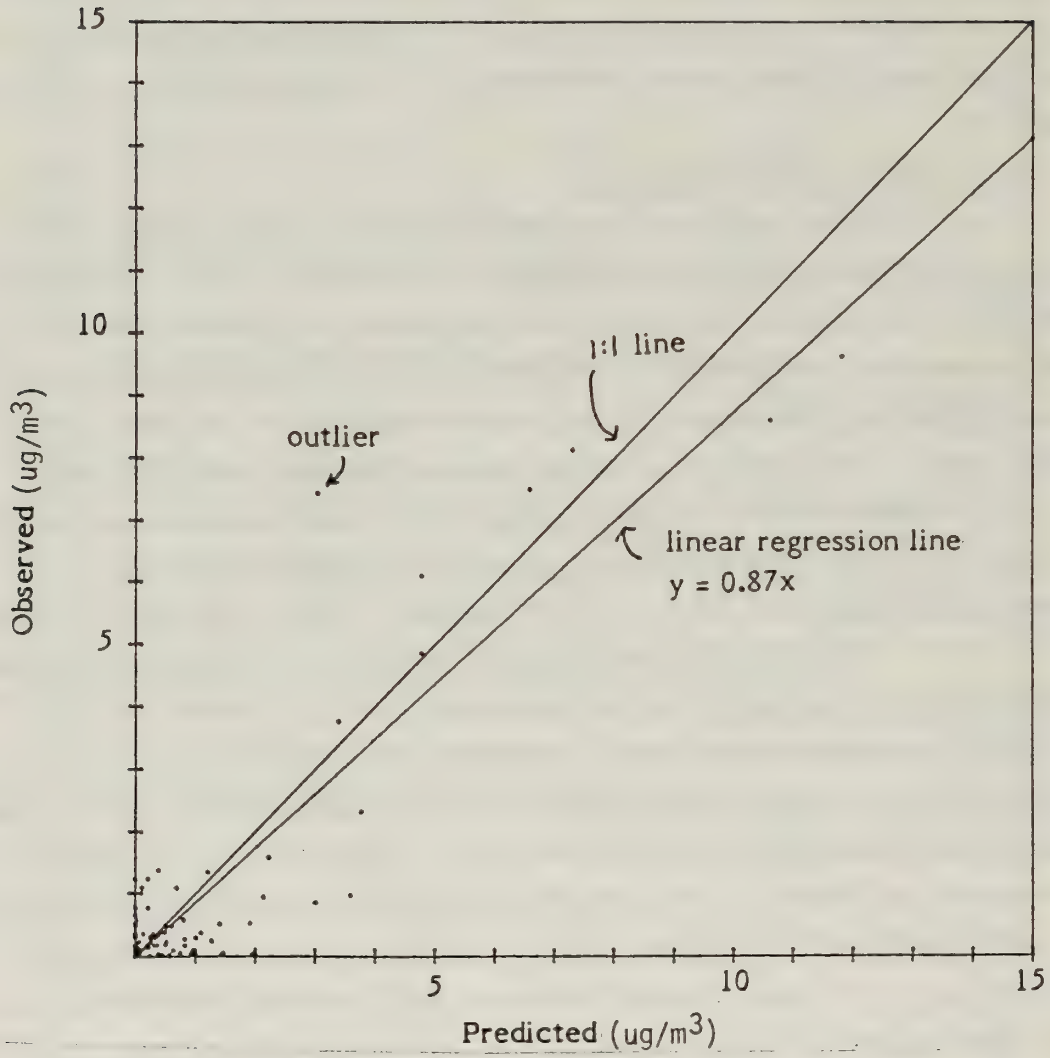


Figure 2 - Predicted versus observed concentrations for AVMSTM Model. Low values (≤ 0.05 μg/m^3) are excluded from the plot.

The analysis results are almost identical to those obtained for the entire data set. The correlation coefficient, the intercept and the slope for the plot presented on pages 3-7 of Appendix 7 are 0.91, 0.01 ug/m^3 and 0.87 respectively. This indicates that inclusion of the low readings does not have any significant effect on the statistics.

The statistics do not change significantly even when more low values are eliminated. The correlation coefficient, the intercept and the slope for the data set with the elimination of all data pairs with values of less than or equal to 0.05 ug/m^3 are 0.88, -0.11 ug/m^3 and 0.89.

(2) The standard error of the estimate, based on the validation results using all data points, is $\pm$ 0.64 ug/m^3. In other words, the overall accuracy of the model is $\pm$ 0.64 ug/m^3, or $\pm$ 7% of the highest observed value.

(3) Referring to Figure 2 the model overpredicts when observed concentrations are greater than 8.50 ug/m^3, underpredicts when observed concentrations are less than 8.50 ug/m^3 and greater than 6.00 ug/m^3, and predicts very well when observed concentrations are less than 6.00 ug/m^3 and greater than 3.00 ug/m^3. Below 3.00 ug/m^3, there is a lot of scatter. Ignoring the low values and the outlier, the model overpredicts at the high end by about 23% and underpredicts when observed concentrations are less than 8.50 ug/m^3 and greater than 6.00 ug/m^3 by about 15%. This implies that the model has an accuracy of $\pm$23% when predicting high ground level pollutant concentrations.

(4) A comparison of predicted-versus-observed SF_6 concentrations at Station 20 (Collins Overlook) is presented in Figure 3. There were only two hours when SF_6 concentrations were detected. Even then, the values were lower than 0.50 ug/m^3. The model predicted zero concentration during one of those hours and predicted the observed concentration for the other hour. This is in line with model behavior pointed out in the previous paragraph; namely when observed concentrations are low, there is a lot of scatter in the predicted values.

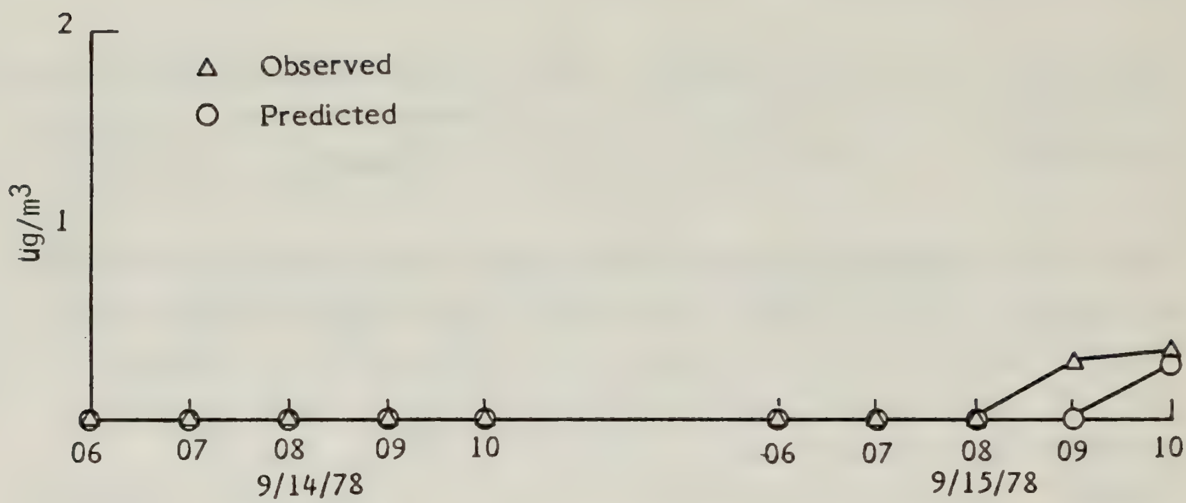


Figure 3 - Trend analysis of predicted and observed SF_6 concentrations at Station 20 as obtained from AVMSTM Model.

These additional analyses further substantiate the predictive capability of the model when applied to Tract C-b. To summarize, the model overpredicts the highest observed concentrations by about 23%, underpredicts observed concentrations in the medium to high range by about 15%, predicts almost exactly observed concentrations in the low to medium range and has a random nature in its predictions when observed concentrations are low. On the average the model overpredicts by 13%.

4.4 Dry Deposition

In line with the Gaussian plume approach for simulating dispersion of gaseous air pollutants, particulate concentrations are calculated by means of a "tilted plume" approach, as discussed in Atmospheric Diffusion (Pasquill, 1974). The Gaussian equation of the Valley Model, modified to include dry desposition is:

$$X = \frac{Q}{2\pi \bar{u} \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \exp\left(-\frac{(H - V_d x/\bar{u})^2}{2\sigma_z^2}\right)$$

where:

X - is the concentration at ground level

Q - the source strength

σ_y, σ_z - the standard deviations of plume horizontal and vertical concentration distributions

$\bar{u}$ - the mean wind speed

H - the effective stack height

V_d - the gravitational settling speed of particles and,

x - the downwind distance.

Figure 4 is a schematic representation of the tilted plume model. The tilting accounts for the fact that, in a nonturbulent atmosphere, application of the simplest ballistic principle, with particle inertia neglected, would place the ground impact of particles at a distance of H/V_d downwind, where is the mean wind speed between the ground and the height of release, or effective stack height, H, and V_d is the gravitational settling speed of the particles. Here, the image source term is omitted since materials reaching the ground are assumed to stay there.

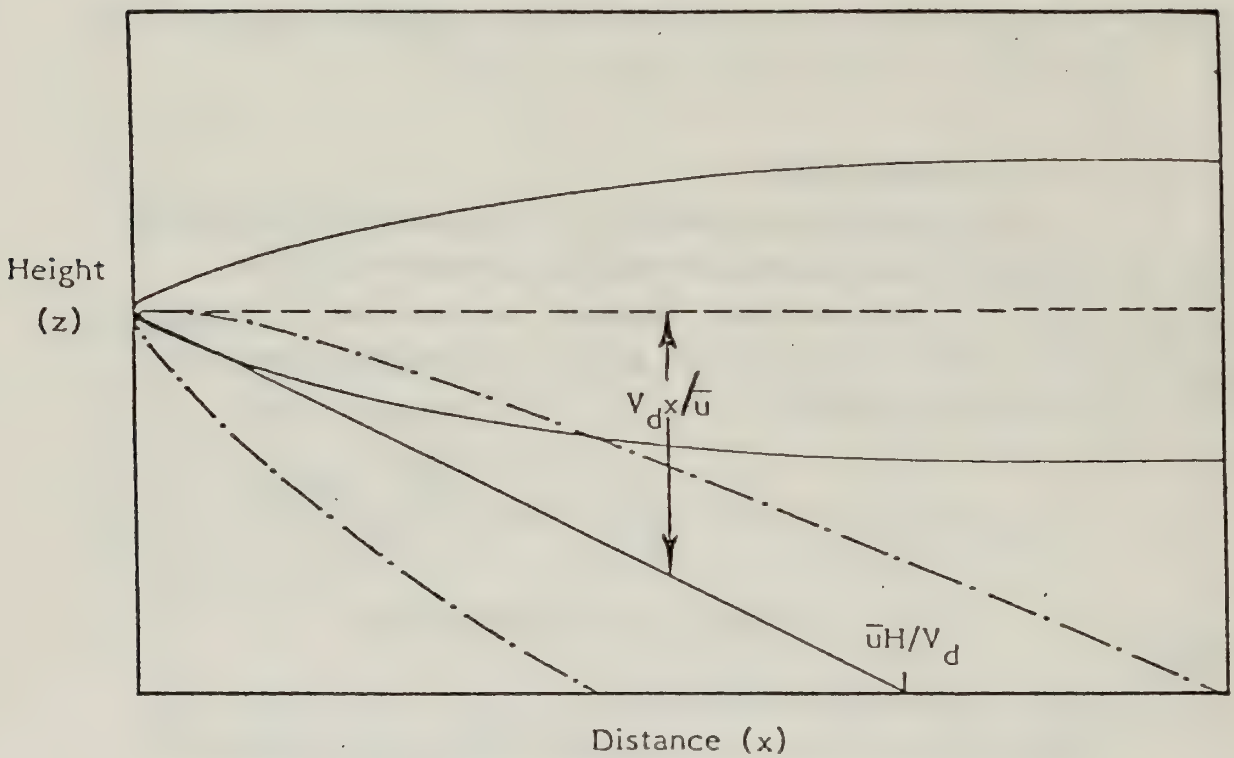


FIGURE 4 - Schematic Representation of Tilted Plume Treatment of Heavy Particles at Velocity V_d (i.e., Dry Deposition).

V_d is calculated from the well-known Stoke's equation:

$$V_d = \frac{2\ r^2 g\rho}{9\mu}$$

where: V_d = settling speed ($cm \cdot sec^{-1}$)

r = radius of the spherical particle (cm)

g = gravitational acceleration ($cm\ sec^{-2}$)

= density of the spherical particle ($gm\ cm^{-3}$)

= atmospheric dynamic viscosity ($gm\ cm^{-1}\ sec^{-1}$)

An atmospheric dynamic viscosity of 0.0180 $gm\ cm^{-1}\ sec^{-1}$ (Schlichting, 1968) and an average particle density of 2.3 $gm\ cm^{-3}$ (U.S. EPA, 1976) are assumed.

4.5 Plume Rise and Effective Stack Height

The plume rise formulation utilized for buoyant plumes is that due to Briggs as contained in the Valley Model. See Table 8, items IA and IB, for Pasquill-Gifford stable and unstable or neutral cases respectively. Additionally plum rises for jets (non-buoyant) were calculated and input to the model using Briggs' formulations, shown as items IIA and IIB for unstable or neutral and stable cases respectively. The major jet sources for which plume rise was calculated are: the two mine vents, the secondary and tertiary crusher, conveyor transfer tower, and the spent shale handling and disposal wet scrubber, designated later in the report as emisson sources 43 and 44, 19, 23 and 29 respectively.

Effective stack height for a specified atmospheric stability class is a term utilized in diffusion modeling and is defined as the sum of the actual stack height plus the final plume rise. For annual-average conditions which utilize bivariate-frequency wind distributions by stability class, one effective stack height is not appropriate inasmuch as it varies with stability and wind speed.

4.6 Emission Sources Modeled

The following pollutants have been modeled: sulfur dioxide (SO_2), total suspended particulates (TSP), carbon monoxide (CO) and nitrogen dioxide (NO_2); all of these are modeled to demonstrate compliance with

TABLE 8

PLUME RISE FORMULAS

I. Buoyant Plumes (as contained in Valley Model)

$$F = \frac{g}{\pi} \; V_F \; \left(\frac{T_e - T_a}{T_e}\right) \qquad (1)$$

$$V_F = \pi \, r_e^2 \; V_e \qquad (2)$$

A. Stable Cases

E, F Stability:

$$\left.\frac{\partial \theta}{\partial z}\right|_{E,\,F} = 0.020,\ 0.035\ {}^{o}K/m \qquad (3)$$

$$s = g \; \frac{\partial\theta/\partial z}{T_a} \qquad (4)$$

$$x_f = \pi \, \bar{u} \; s^{-1/2} \qquad (5)$$

for $x < x_f$:

$$\Delta h_x = 1.6 \; F^{1/3} \; x^{2/3} \; \bar{u}^{-1} \qquad (6)$$

for $x \geq x_f$:

$$\Delta h_f = \text{lowest of} \begin{cases} 2.4 \left(\dfrac{F}{\bar{u}s}\right)^{1/3} & (7a) \\[2ex] 5.0 \; F^{1/4} s^{-3/8} \\ \quad (\text{calm}) & (7b) \end{cases}$$

B. Unstable or Neutral

for $F < 55$:

$$x^* = 14F^{5/8} \qquad (8)$$

for $F \geq 55$:

$$x^* = 34F^{2/5} \qquad (9)$$

$$x_f = 3.5 \; x^* \qquad (10)$$

for $x < x_f$:

$$\Delta h_x = 1.6F^{1/3} \; x^{2/3} \; \bar{u}^{-1} \qquad (11)$$

for $x \geq x_f$:

$$\Delta h_f = 1.6 F^{1/3} \; x_f^{2/3} \; \overline{u}^{-1} \tag{12}$$

where: F = buoyancy flux (m^4/s^3)

g = gravitational acceleration

= 9.806 m/s^2

V_F = stack gas volumetric flow rate (m^3/s)

T_e = stack gas exit temperature (^oK)

T_a = ambient air temperature (^oK)

r_e = stack radius (m)

V_e = stack gas exit speed (m/s)

$\frac{\partial\theta}{\partial z}$ = potential temperature gradient ($^oK/m$)

x = downward distance from the stack (m)

x_f = downward distance to final plume rise (m)

$\overline{u}$ = mean wind speed (m/s)

Δh_x = plume rise to any x (m)

Δh_f = final plume rise (m)

II. Jets (as calculated and input to Valley Model)

A. Unstable & Neutral

$$\Delta h_f = \frac{3.82 \; V_F}{(2r_e) \; \overline{u}} \tag{13}$$

B. Stable

$$\Delta h_f = 1.5 \left(\frac{F_m}{\overline{u}}\right)^{1/3} s^{-1/6} \tag{14}$$

where:

$$F_m = \frac{\rho_e}{\rho_a} V_e^{\;2} \quad r_e^{\;2} \tag{15}$$

ρ_e = density of exit gases

ρ_a = density of ambient air

ambient standards and, in addition SO_2 and TSP are modeled to demonstrate compliance with PSD increments.

Sources may be characterized as point, line, or area sources. A stack is an example of a point source, an ore conveyor of a line source, and a raw shale pile of an area source.

General arrangement of emission source locations is presented on the C.B. Plot Plan (Figure 5) in this section and on Drawing No. EM-105 in Appendix 4.0 including the raw and spent shale stockpiles. Emission sources near the shale processing area are shown on Drawing No. EM-103 in the same Appendix. The Valley Model treats only a finite number of point sources and square-shaped area sources so that three approximations to model source inputs have been made:

1. Sources in close proximity to each other have been combined (e.g., 8 closely located Lurgi trains, 7 of which operate at any one time have been grouped as follows: Group 1 (trains 1 & 5) Group 2 (trains 2, 6, 7) and Group 3 (4 & 8);
2. Line sources such as conveyor belts have been treated equivalently as point sources of equavalent source strength evenly spaced along the conveyor belt;
3. The exposed or working faces of shale and topsoil piles have been approximated by a series of adjoining square blocks whose total area approximates the area of the working face.

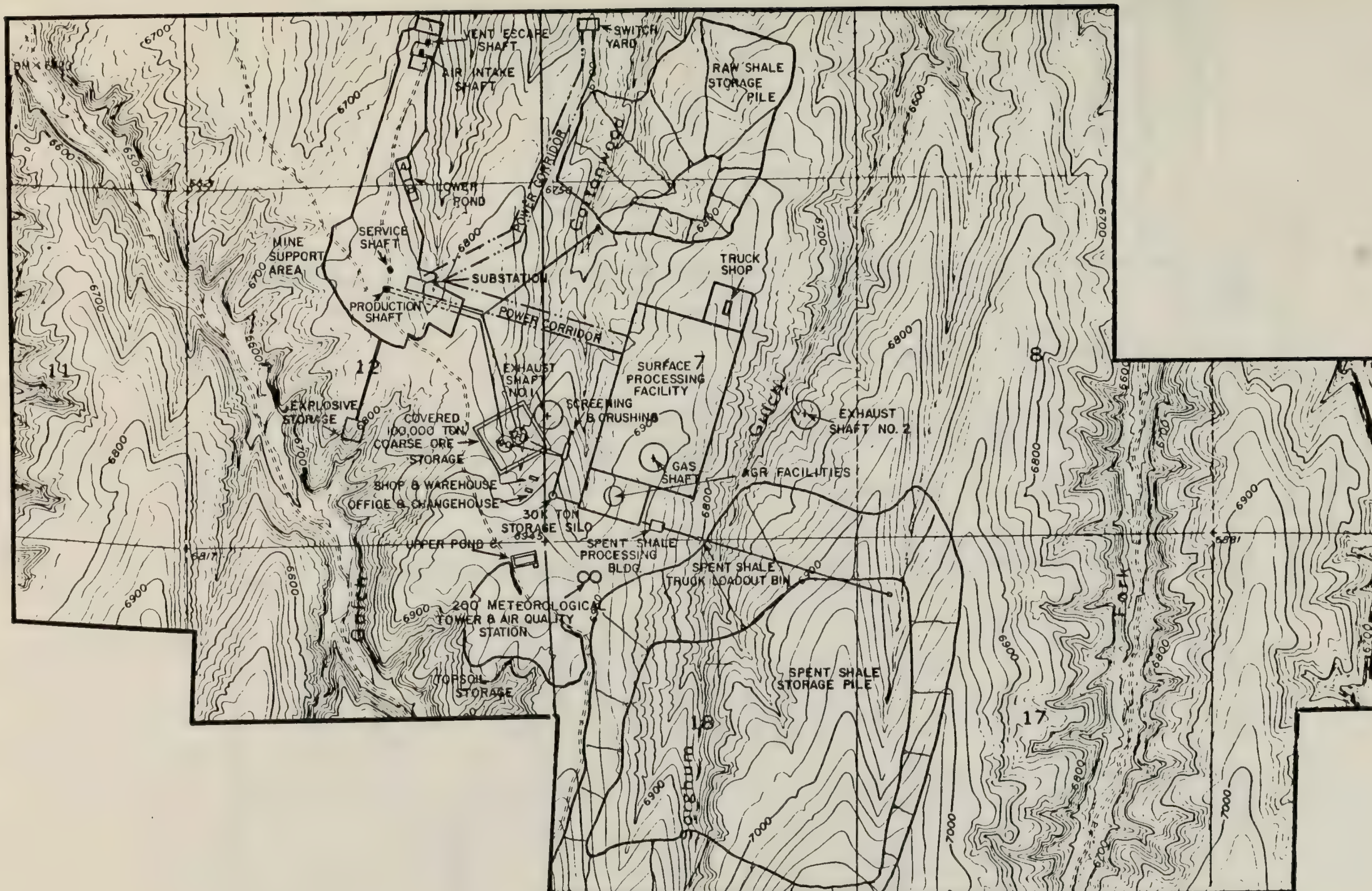
Secondary emission sources from the towns of Meeker and Rifle and associated traffic from these towns have also been modeled and are discussed in Section 7.0.

Emission source strengths and locations and control efficiencies for primary sources are identified on Drawing Nos. EM-104 and Oxy 2 of Appendix 4.0. Table 9 summarizes the as-modeled emissions tables (i.e., their identification and location in the Appendix). Table 10 summarizes total controlled emissions from primary sources on the C-b Tract.

5.0 <u>SO_2 Modeling</u>

5.1 Emission Sources

SO_2 emission sources include the following:



CB PLOT PLAN
SHALE STORAGE YEAR 2000

FIGURE 5

TABLE 9

SUMMARY OF THE AS-MODELED EMISSIONS TABLES

Item	Primary/ Secondary	Table Number In Appendix 11.	No. of Pages In The Table
Emission Sources As-Modeled	Both	11.1	2
Emission Source Strengths			
SO_2	Primary	11.2	1
TSP	Primary	11.3	25
CO	Primary	11.4	1
NO_x	Primary	11.4	1
TSP Mass Dist.	Primary	11.5	1
SO_2	Secondary	11.6	7
TSP	Secondary		
CO	Secondary		
NO_x	Secondary		
Emission Sources Locations			
All	Primary	11.7	7
All	Secondary	11.8	3

TABLE 10

Total Controlled Emissions from Primary Sources

Constituent	gm/sec	lb/hr	TPD	lbs/bbl[1]	lbs/bbl[5]
SO_2-24hr & Ann	236	1870	22.5	0.38	0.29
NO_x-Annual	956	7578	91.0	1.55	1.17
CO-1 hr[3]	362	2873	34.5	0.60	0.45
CO-8 hr[4]	330	2616	31.4	0.54	0.41
TSP-24 hr[2]	103	814	9.8	0.17	0.13
TSP Annual[2]	88	703	8.4	0.14	0.11

(1) Based on 117,000 bbls/day

(2) Based on year 25 shale pile development as worst case.

(3) Based on worst 1-hour

(4) Based on worst 8-hour

(5) Based on 155,000 bbls/day which includes 38,000 bbl gas-equivalent

Emission Source Number	Source Description
43,44	Mine Exhaust Shafts #1 & #2
52-56	FGD Stacks #1 to #5
58	11 Temporary Power Generators
60	Cement Batch Plant Boiler
61	Lurgi Stacks #1 & #5
62	Lurgi Stacks #2, #6, #7
63	Lurgi Stacks #4, #8

Source locations are shown on drawings EM-102 and EM-103 of Appendix 4.0. Control system characteristics are shown on drawing Oxy 2 of Appendix 4.0. Emission source coordinates, as-modeled emission magnitudes and stack characteristics are shown on drawing EM-105 of Appendix 4.0.

5.2 Results

5.2.1 PSD Compliance

PSD increments pertain to both SO_2 and TSP; the magnitude of the increments differ for Class I and Class II areas as shown on Table 4. Primary and secondary effects are both considered. The primary effects of SO_2 in Section 5.2.1.1 (Class I) and Section 5.2.1.2 (Class II) are those due to emission sources originating on Tract. Basinwide impacts are considered in Section 7.0 as are other currently permitted primary and secondary sources.

5.2.1.1 Class I

The Flattops Wilderness area is approximately 57 km from the C-b Tract and is the closest Class I area to the Tract. Compliance with Class I PSD increments is demonstrated on Table 1, inasmuch as all Class I maximum modeling increments are less than the respective PSD increments. Annual isopleths for SO_2 as obtained from the Valley Model are presented on Figure 6 yielding 0.06 ug/m^3 at the Flattops boundary compared with the standard of 5.0. Twenty-four hour and three-hour SO_2 values are estimated to be approximately zero at Flattops on the basis of examination of the isopleths of Figures 7 and 8 respectively. They have been cross-plotted on a semi-log plot on Figure 9 in the direction of Flattops. Concentrations drop to 0.01 ug/m^3 as distances from C-b of 9 and 12 km for three-hour and twenty-four hour cases respectively.

5.2.1.2 Class II

Compliance with Class II PSD increments is demonstrated on Table 1 inasmuch as all Class II maximum modeling increments are less than the respective PSD increments.

FIGURE 6

CLASS I ANNUAL SO_2 CONCENTRATIONS

(ug/m^3)

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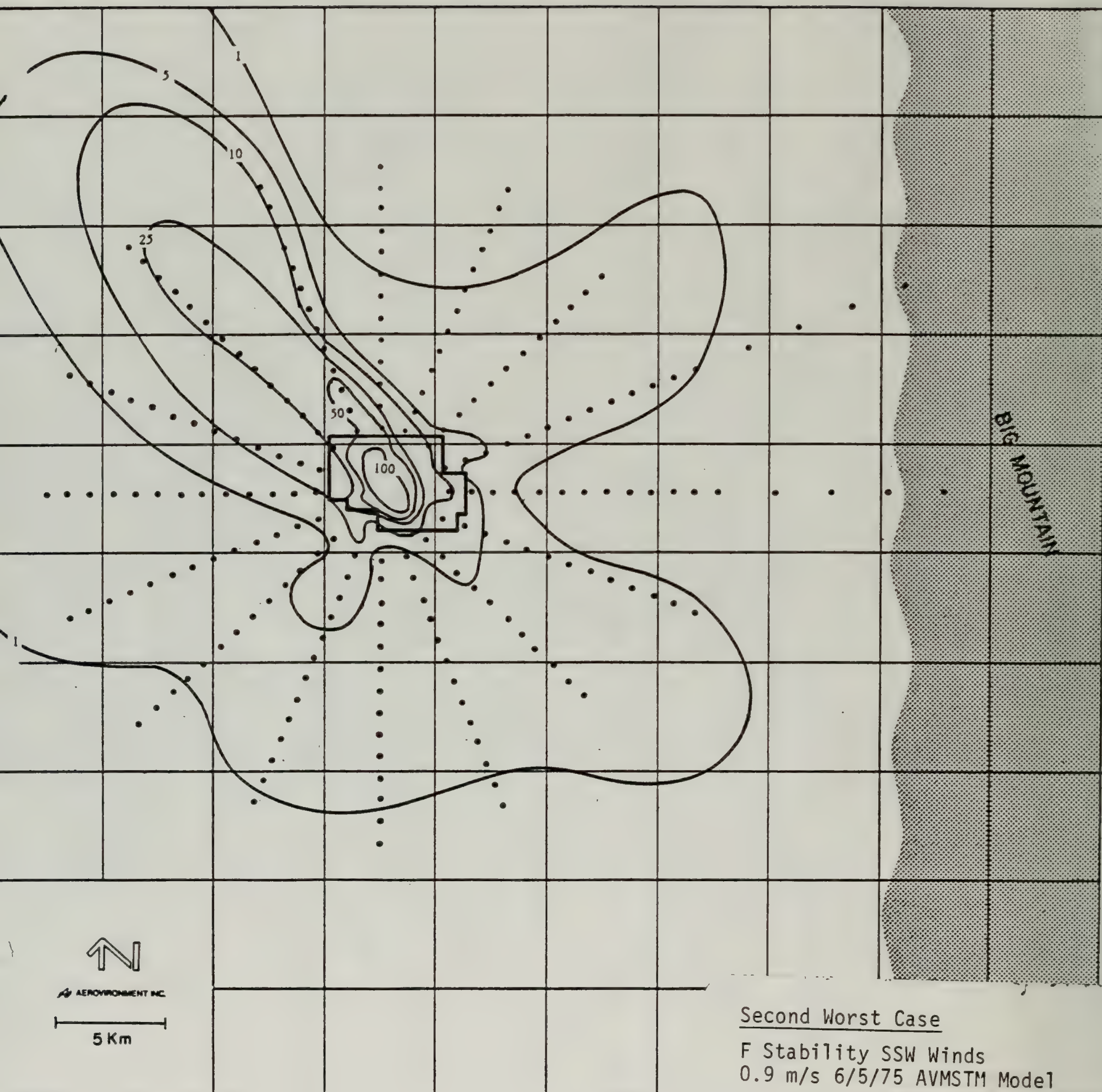


Figure 7 - Class II 24-Hour SO_2 Concentrations

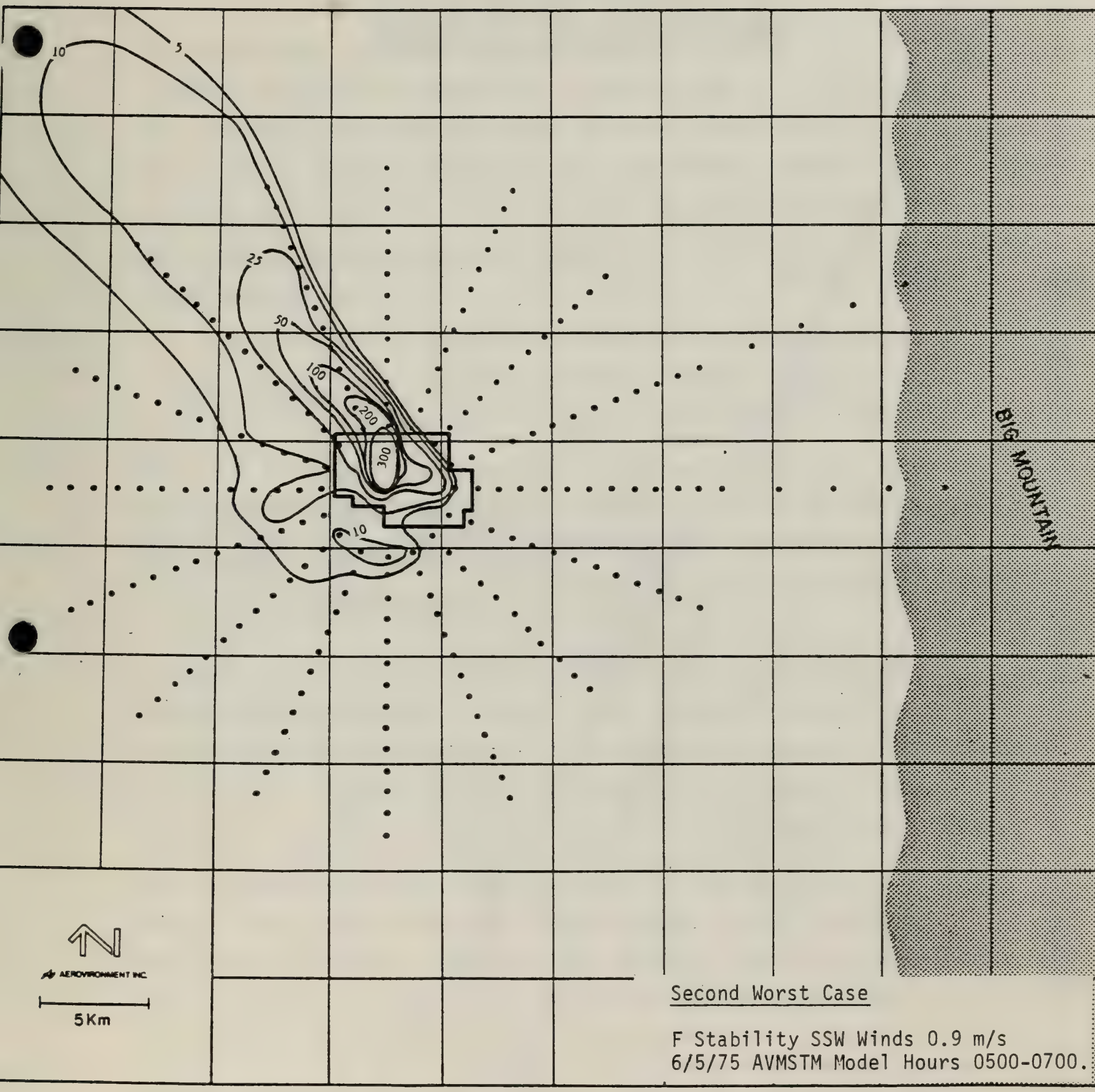


Figure 8 - Class II 3-Hour SO_2 Concentrations

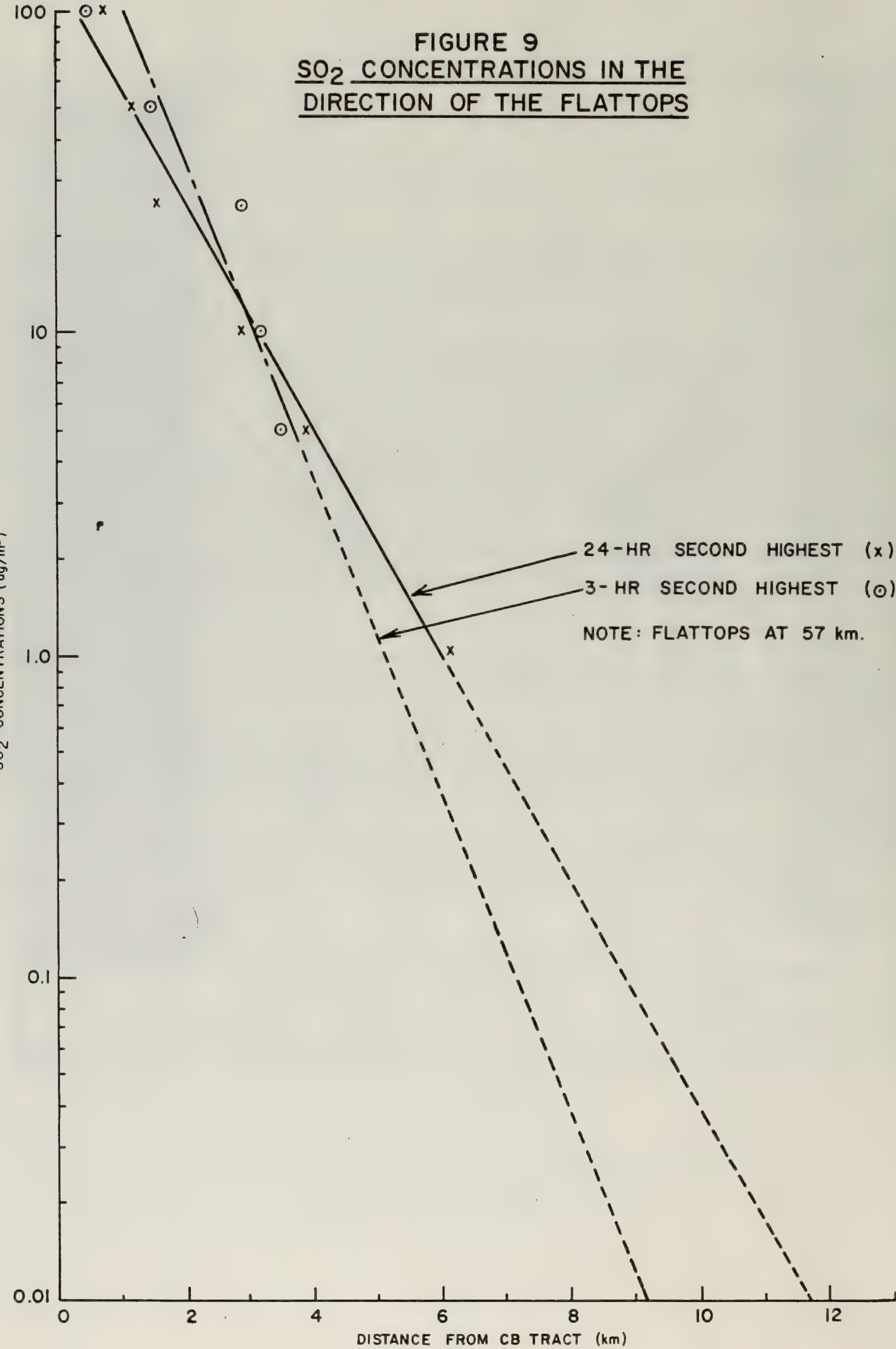


FIGURE 9
SO_2 CONCENTRATIONS IN THE DIRECTION OF THE FLATTOPS
24-HR SECOND HIGHEST (x)
3-HR SECOND HIGHEST (⊙)
NOTE: FLATTOPS AT 57 km.
100
10
1.0
0.1
0.01
0
2
4
6
8
10
12
DISTANCE FROM CB TRACT (km)

The critical cases (worst and second worst) for SO_2 corresponded to 24-hour averaging times under stable conditions (cases 18 and 17 of Table 5) in the initial screening mode using the Valley Model; they resulted in high concentrations for stack heights for the principal buoyant sources of 34 and 30 meters for FGD's and Lurgi's respectively. All other SO_2 cases resulted in low concentrations in the initial screening mode. The AeroVironment refined rough terrain model (AVMSTM) was then utilized to study short-term SO_2 concentrations for stable conditions. Resulting concentrations off-tract were:

Worst Case - 6-hr persistence of SSW winds for E Stability @ 1.0 m/s yielded 79 ug/m^3;

Second Worst Case - 6-hr persistence of SSW winds for F Stability @ 0.9 m/s yielded 73 ug/m^3.

Both cases are below the 24-hour PSD standard of 91 ug/m^3. Isopleths for the second-worst case are presented on Figure 7, showing the peak concentration off-tract of 73 ug/m^3 as previously mentioned. Second-worst off-tract concentrations (303 ug/m^3) for the 3-hour standard were not critical (Figure 8) and were below the standard of 512 ug/m^3.

In the course of this study it was found that because of the large plume rise of the Lurgi & FGD buoyant stacks, the Federal standard off-tract was not limiting. Then, on-tract concentrations of SO_2 were checked from the standpoint of a "workplace environment". That is, the Federal 3-hour secondary standard of 1300 ug/m^3 was required to be met everywhere (i.e. both on-and off-tract). Ambient SO_2 concentrations were checked for D stability at a 24-hour persistent wind at 10.8 m/s and an A stability 6-hour persistent wind at 7.8 m/s with the former found to be more severe. Peak concentrations near the MIS process area were found to be approximately 615 ug/m^3. Concentrations were also examined atop the 95 m service shaft at a distance of 1280 m from the MIS units and found to be much lower than concentrations in the process area.

Isopeths for the annual case were run in the initial screening process and are shown on Figure 10. Peak off-tract concentrations were 15.6 ug/m^3 compared to the standard of 20 ug/m^3.

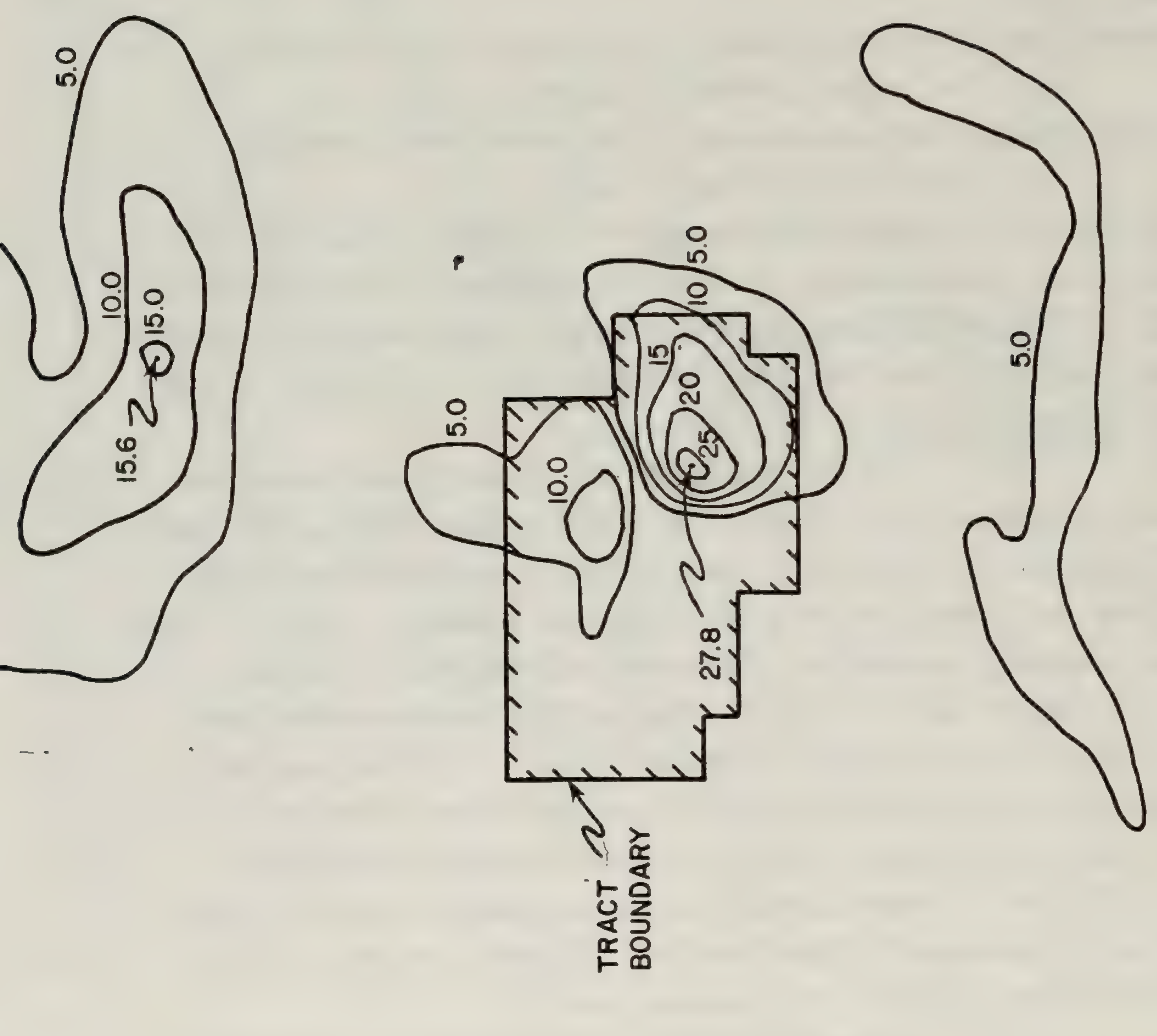


FIGURE 10
CLASS II ANNUAL SO_2 CONCENTRATIONS
(ug/m^3)
JOB 3599

5.2.1.3 Good Engineering Practice (GEP)

EPA's PSD regulations have established that stack heights be limited to what is termed "good engineering practice" (GEP). This is defined as: "'Good engineering practice stack height' means that stack height necessary to ensure that emissions from the stack do not result in excessive concentrations of any air pollutant in the immediate vicinity of the source as a result of atmospheric downwash, wakes, or eddy effects which may be created by the source itself, nearby structures, or nearby terrain obstacles and shall not exceed as appropriate:

1) 30 meters, for stacks uninfluenced by structures or terrain:
2) GEP = H + 1.5 L

where

GEP = good engineering practice stack height
H = height of structure or nearby structure
L = lesser dimension (height or width) of the structure or nearby structures."

Furthermore, "nearby" "is defined for a specific structure or terrain feature, and means that distance equal to five times the lesser of the height or width dimension of a structure or terrain not greater than one-half mile (0.8 km)".

As part of the facility relevant tall structures include:

	Height (m)	Minimum Length or Width (m)	GEP Height (m)
Ammonia Scrubber	52.1	65.8	9.2
Lurgi Lift Pipe	54.9	69.4	9.6

Both the ammonia scrubber and the Lurgi lift pipe are designed to be greater than 5-times the minimum length (or width) from the FGD or Lurgi stacks respectively to avoid excessive downwash. Therefore, the GEP stack heights for FGD's and Lurgi's of 65.8 and 69.4 meters respectively need only be addressed in terms of general guidance. Model runs were made with 34 and 30 meter stacks respectively but the impacts on the point of

maximum 24-hour SO_2 concentrations are less than -5 and -1 ug/m^3 respectively as obtained from rough-terrain model runs for these stack height differences. As the other extreme, GEP limits the maximum stack height creditable under the regulation.

5.2.2 Compliance with NAAQS

As indicated in Section 3.2, the baseline value for SO_2 is 1 ug/m^3. This is added to the maximum PSD increments to demonstrate compliance as follows:

Averaging Time	(1) Baseline	(2) PSD Baseline	(1)&(2) Total	NAAQS
	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)
24-hr	1	73	74	365
Annual	1	16(rounded)	17	80

This is summarized in Table 2.

5.2.3 Compliance with State Standards

State of Colorado standards are identical with the NAAQS.

6.0 TSP Modeling

6.1 Emission Sources

The 45 fugitive dust sources and 7 particulate point sources are located on drawings EM-101, -102 and -103 of Appendix 4.0. Control system characteristics are given on EM-101. Source coordinates, as-modeled emission magnitudes and stack characteristics are shown on drawing EM-104.

Method of treatment of modeling the shale- and topsoil-piles as fugitive dust sources is as follows. The spent shale pile is assumed to have an exposed area (working face) over time of 50 acres. Location of the exposed area changes as the shale pile grows. Its location for three representative years is shown on Figures 11a-11c for years 10, 15, and 25 respectively. Inasmuch as that location resulting in maximum ground-level plume concentration is not known before the fact, all three years are modeled. Spent shale pile model representation as a series of square blocks is shown on Figures 12a-12c for years 10, 15, and 25 respectively. For example, the spent shale pile for year 10 on Figure 12a is represented by 7 blocks (sources 33a thru 33g). Furthermore, topsoil is scraped from along the base of the exposed pile (source 38 and shown as 11 blocks 38a thru 38k), moved by truck and

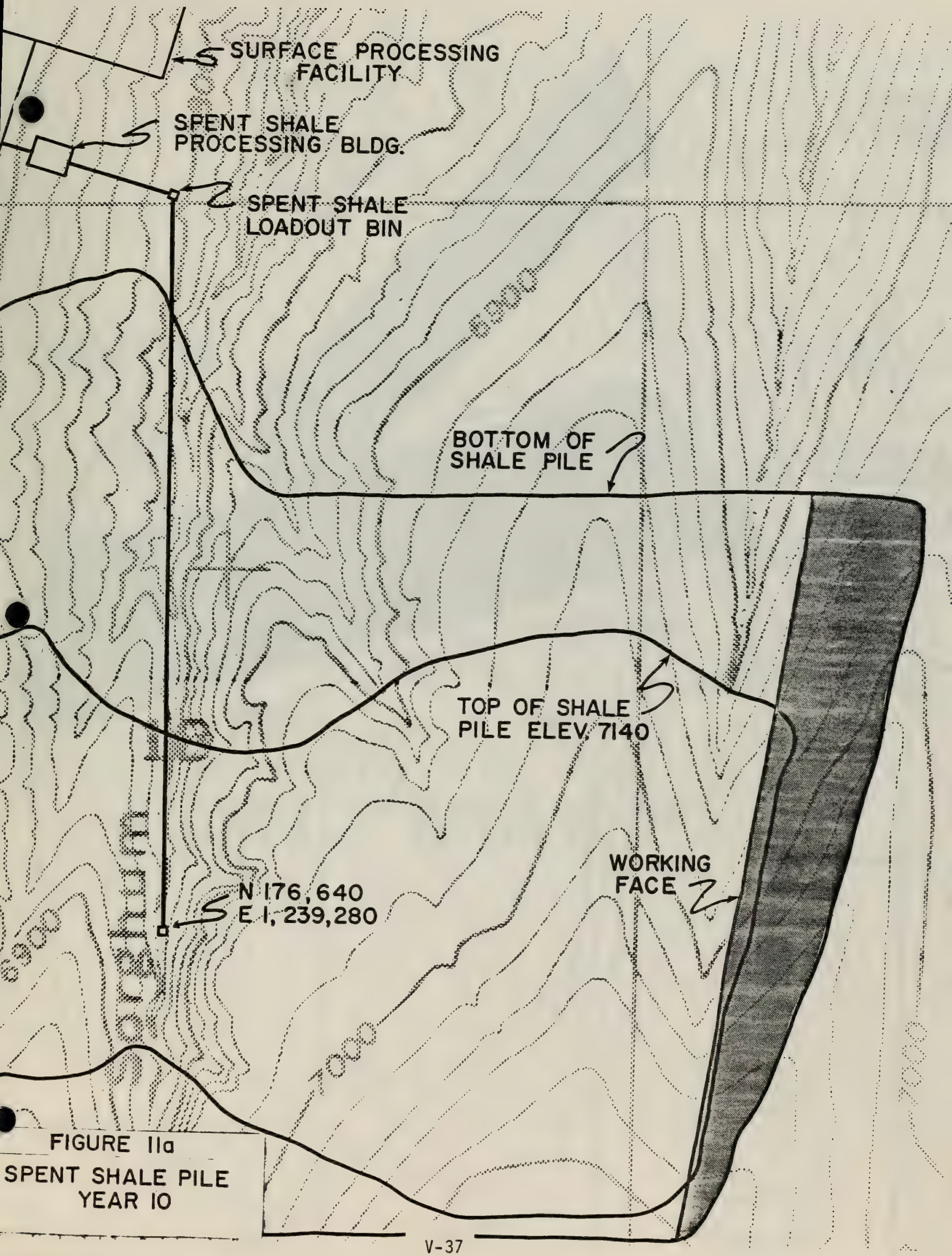


FIGURE 11a
SPENT SHALE PILE
YEAR 10

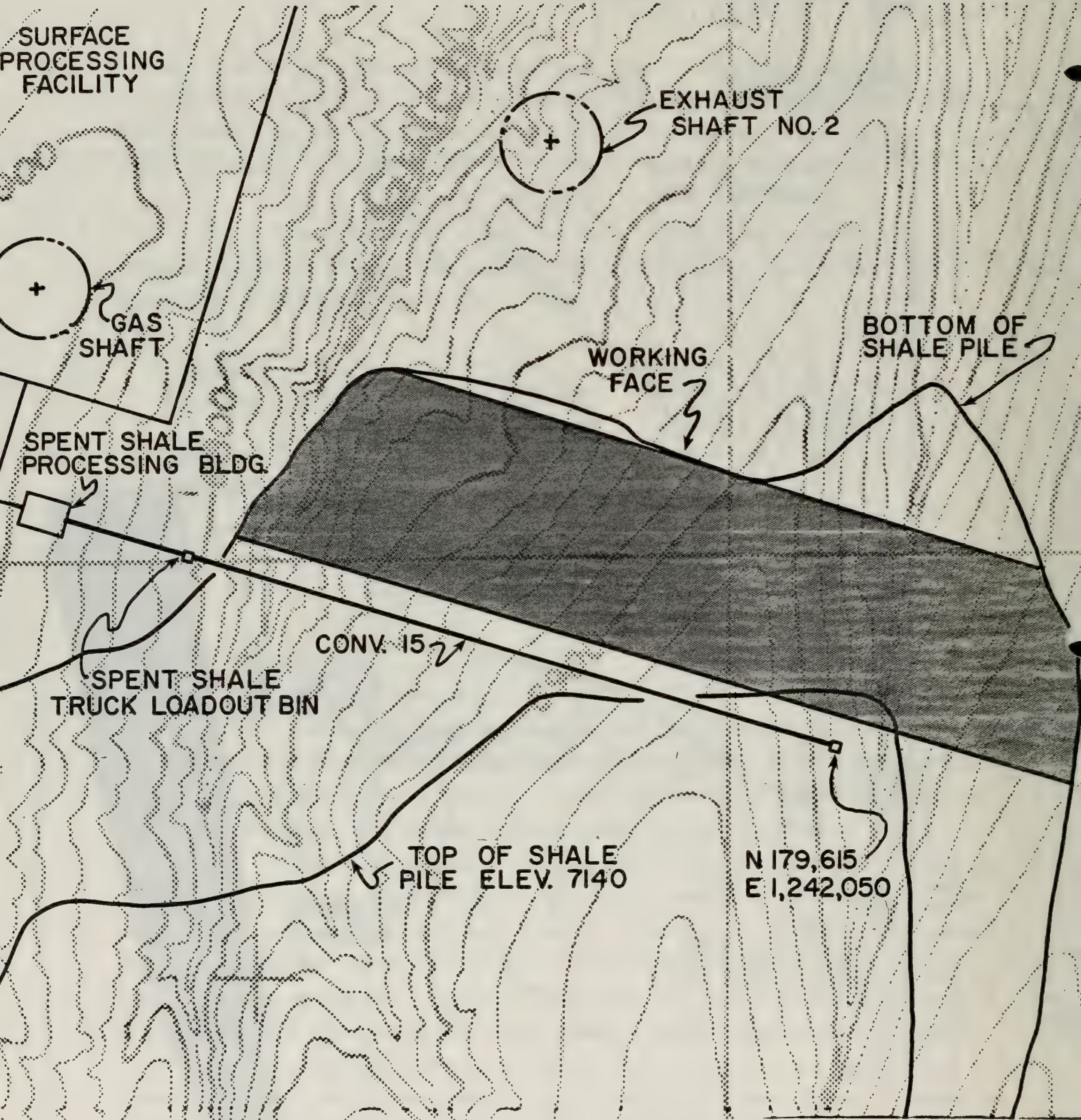


FIGURE 11b

SPENT SHALE PILE
YEAR 15

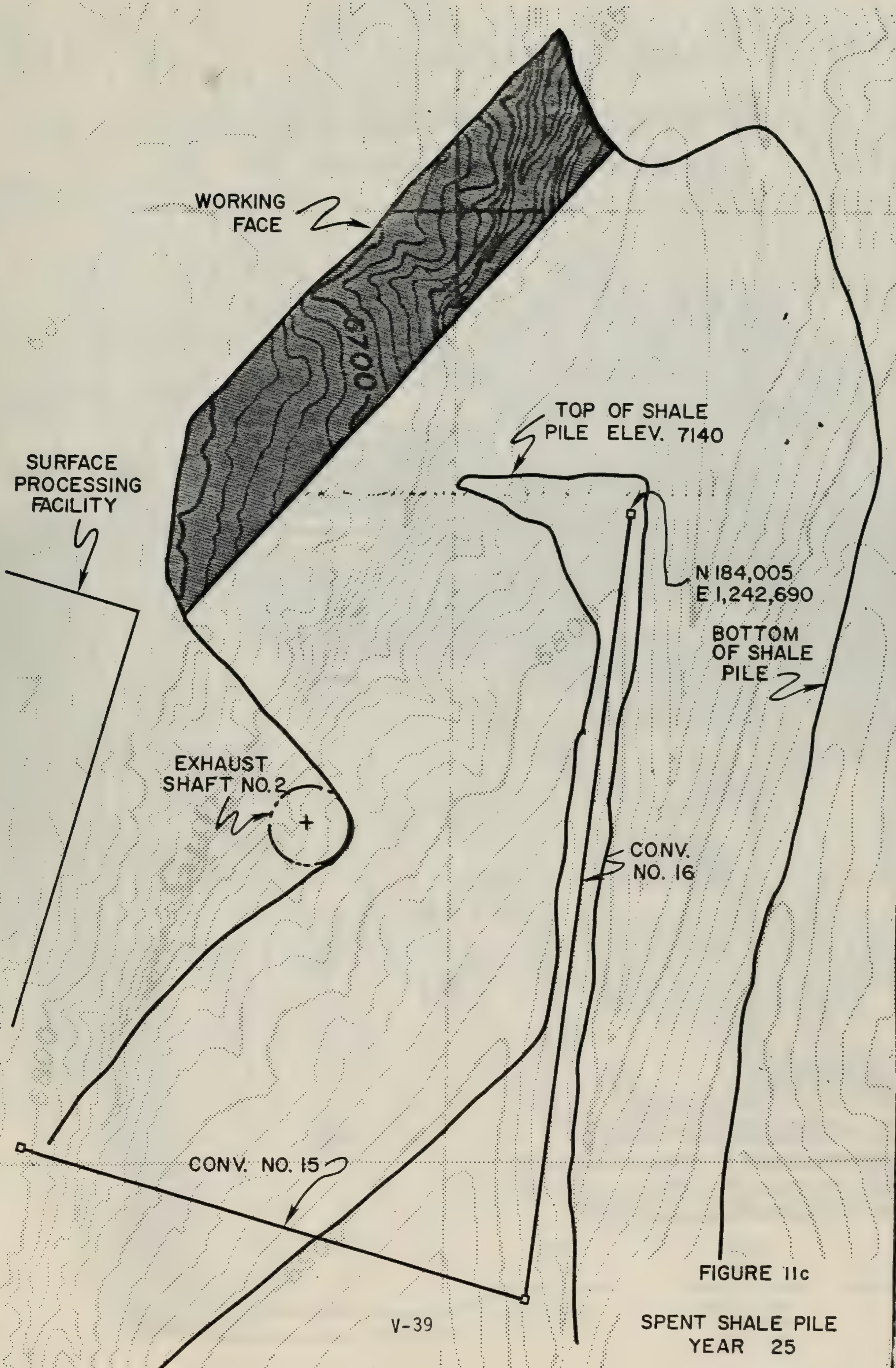


FIGURE 11c

SPENT SHALE PILE
YEAR 25

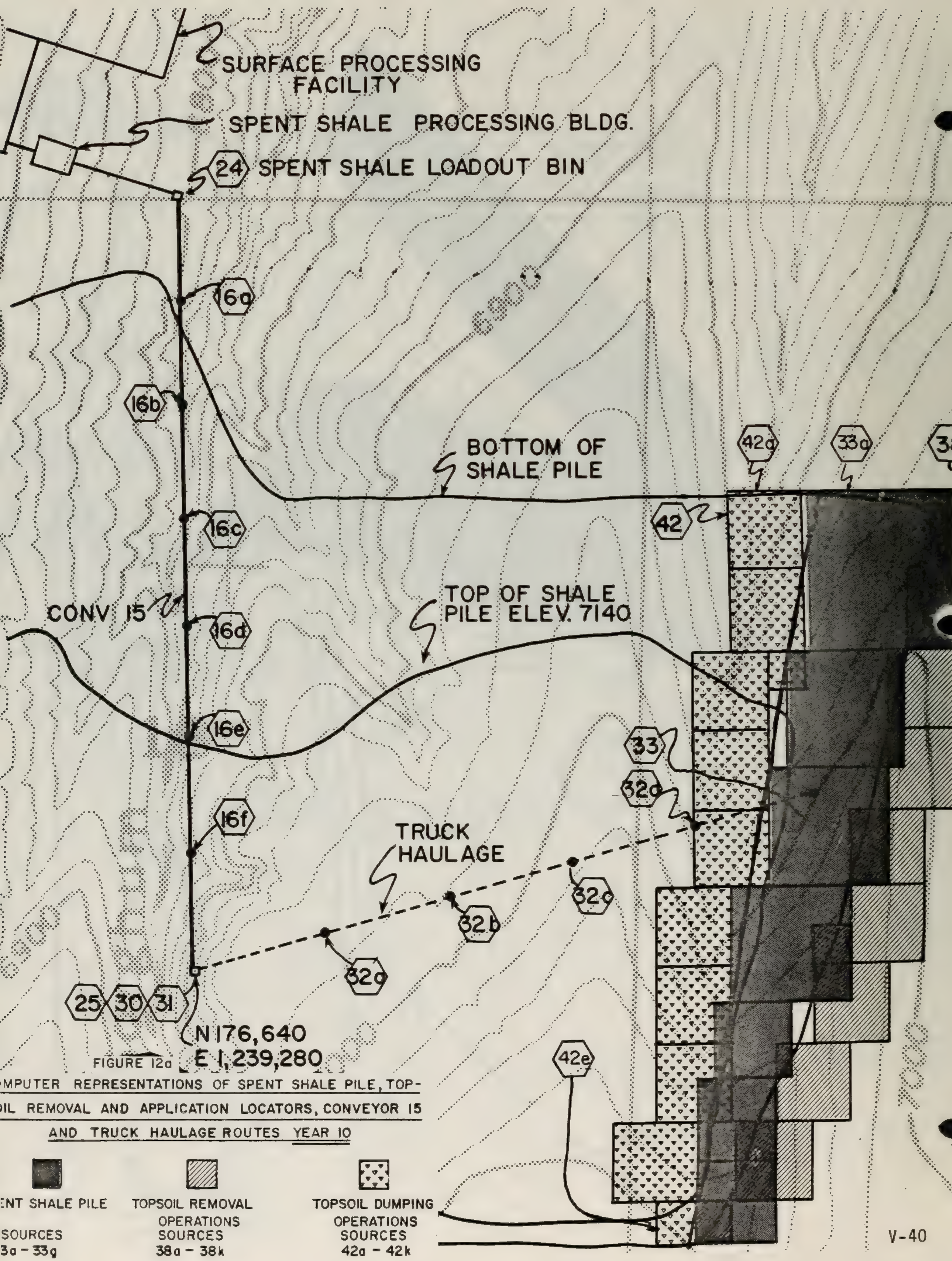


FIGURE 12a

MPUTER REPRESENTATIONS OF SPENT SHALE PILE, TOP-
IL REMOVAL AND APPLICATION LOCATORS, CONVEYOR 15
AND TRUCK HAULAGE ROUTES YEAR 10

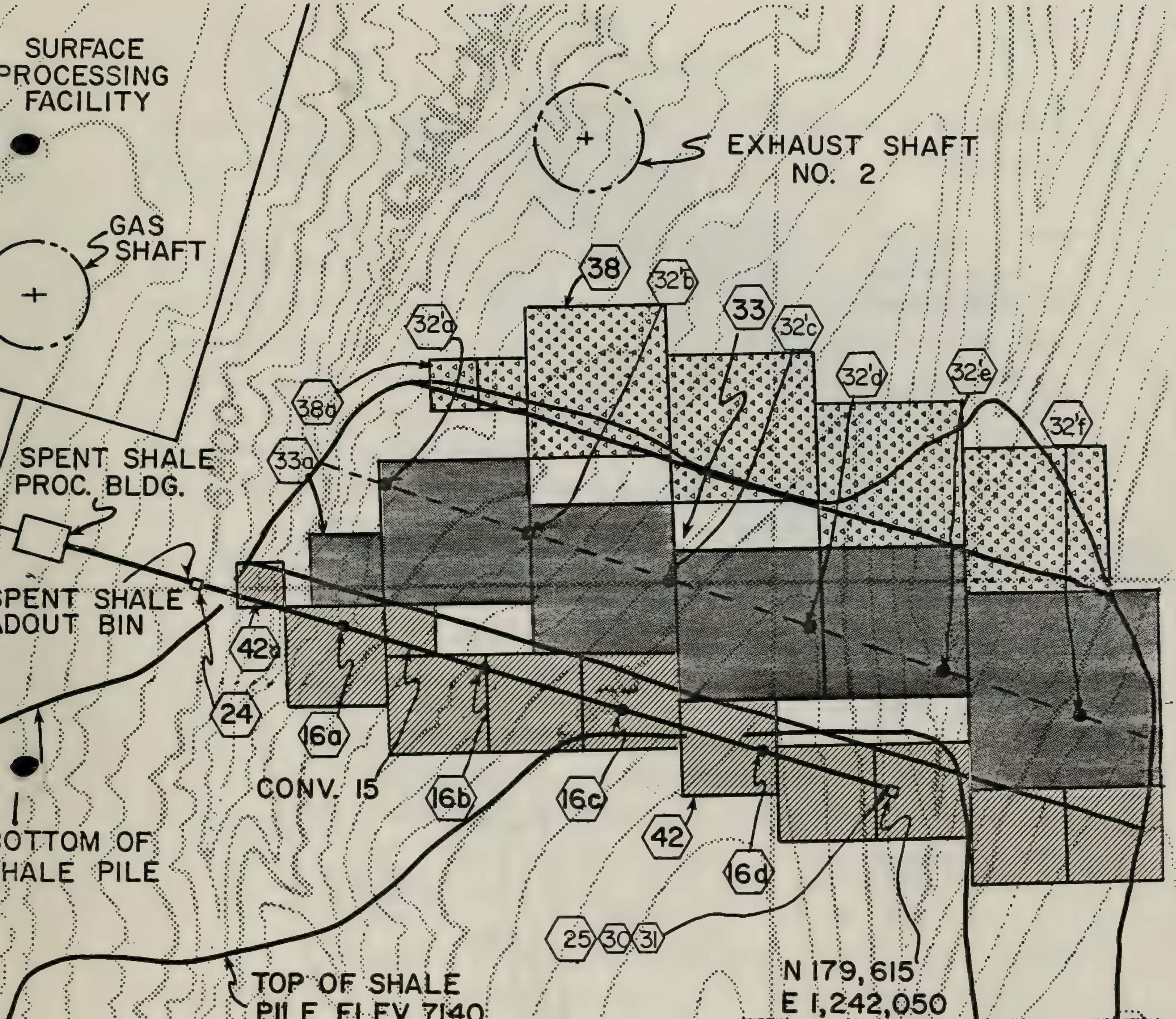


FIGURE 12b

COMPUTER REPRESENTATIONS OF SPENT SHALE PILE, TOPSOIL REMOVAL AND APPLICATION LOCATIONS, CONVEYOR NO. 15 AND TRUCK HAULAGE ROUTES

YEAR 15

SPENT SHALE PILE	TOPSOIL REMOVAL OPERATIONS	TOPSOIL DUMPING OPERATIONS
6 BLOCKS	6 BLOCKS	11 BLOCKS
SOURCES 33a - 33f	SOURCES 38a - 38f	SOURCES 42a - 42k

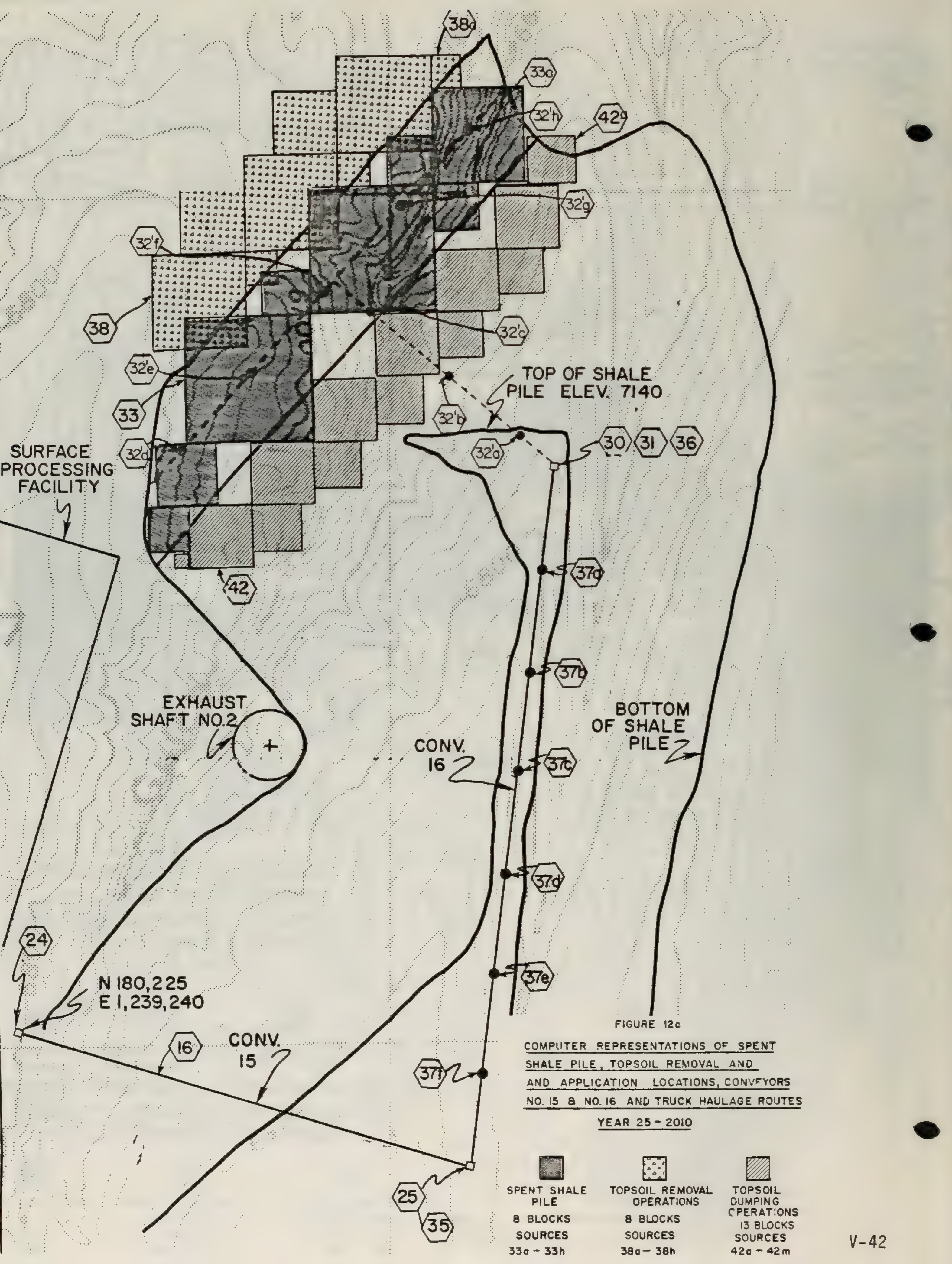


FIGURE 12c

COMPUTER REPRESENTATIONS OF SPENT SHALE PILE, TOPSOIL REMOVAL AND AND APPLICATION LOCATIONS, CONVEYORS NO. 15 & NO. 16 AND TRUCK HAULAGE ROUTES

YEAR 25 - 2010

dumped and spread uniformly along the top of the pile (source 42 and shown as blocks 42a thru 42k). Years 15 and 25 are treated similarly on Figures 12b and 12c.

The raw shale pile is assumed to have an exposed area (working face) over time of 15 acres. Location of the exposed area changes as the shale pile first grows and then contracts to zero. Its location is shown on Figures 13a-13c for years 10, 15, and 25 respectively; again, all these years were modeled. Raw shale pile model representation as a series of square blocks is shown on Figures 14a-14c respectively. In similar fashion to that of the spent shale pile, topsoil is scraped from along the base of the exposed pile, moved by truck, dumped, and spread uniformly along the top of the pile.

The model utilizes the block dimensions and coordinates of the lower left hand corner of the block with regard to shale pile square-area sources.

Shale pile emission factors have assumed the following:

1. Annual emission factors assume 150 days of snow cover.
2. Annual emission factors assume winds (at the 8-foot level of the tower) exceed 12 mph (5.4 m/s) 11% of the time, as substantiated by meteorological-tower wind data.
3. Twenty-four hour emission factors assume winds exceed 12 mph 100% of the time (substantiated by a D stability case with 25 hours of SSW wind @ 10.8 m/s).

Emissions from major particulate sources are assumed to follow the equations of dry deposition as previously described in Section 4.4. Estimates of particle size distributions for these sources (run-of-mine raw shale, 1/2" raw shale, spent shale, topsoil, mine-vent emissions, and Lurgi-stack emissions) are presented on Figure 15.

6.2 Results

6.2.1 PSD Compliance

6.2.1.1 Class I

Twenty-four hour isopleths for TSP are presented on Figure 16 yielding approximately 0.15 ug/m^3 at Flattops compared to the standard of 10.0. The annual isopleth for TSP at 1.0 ug/m^3 is shown on Figure 23 (in section 7.0); extrapolation to Flattops yields 0.03 ug/m^3 compared to the standard of 5.0.

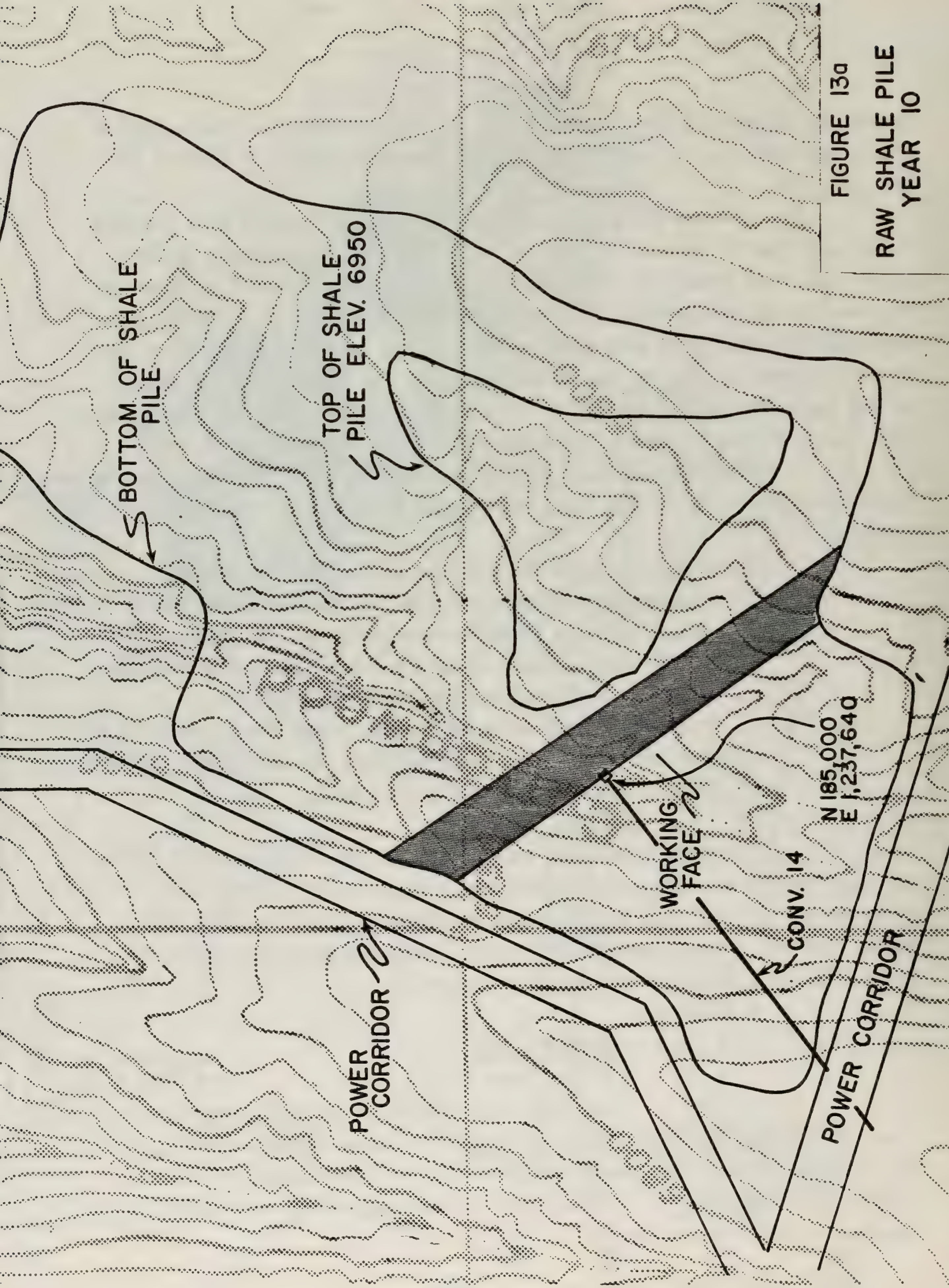


FIGURE 13a
RAW SHALE PILE
YEAR 10

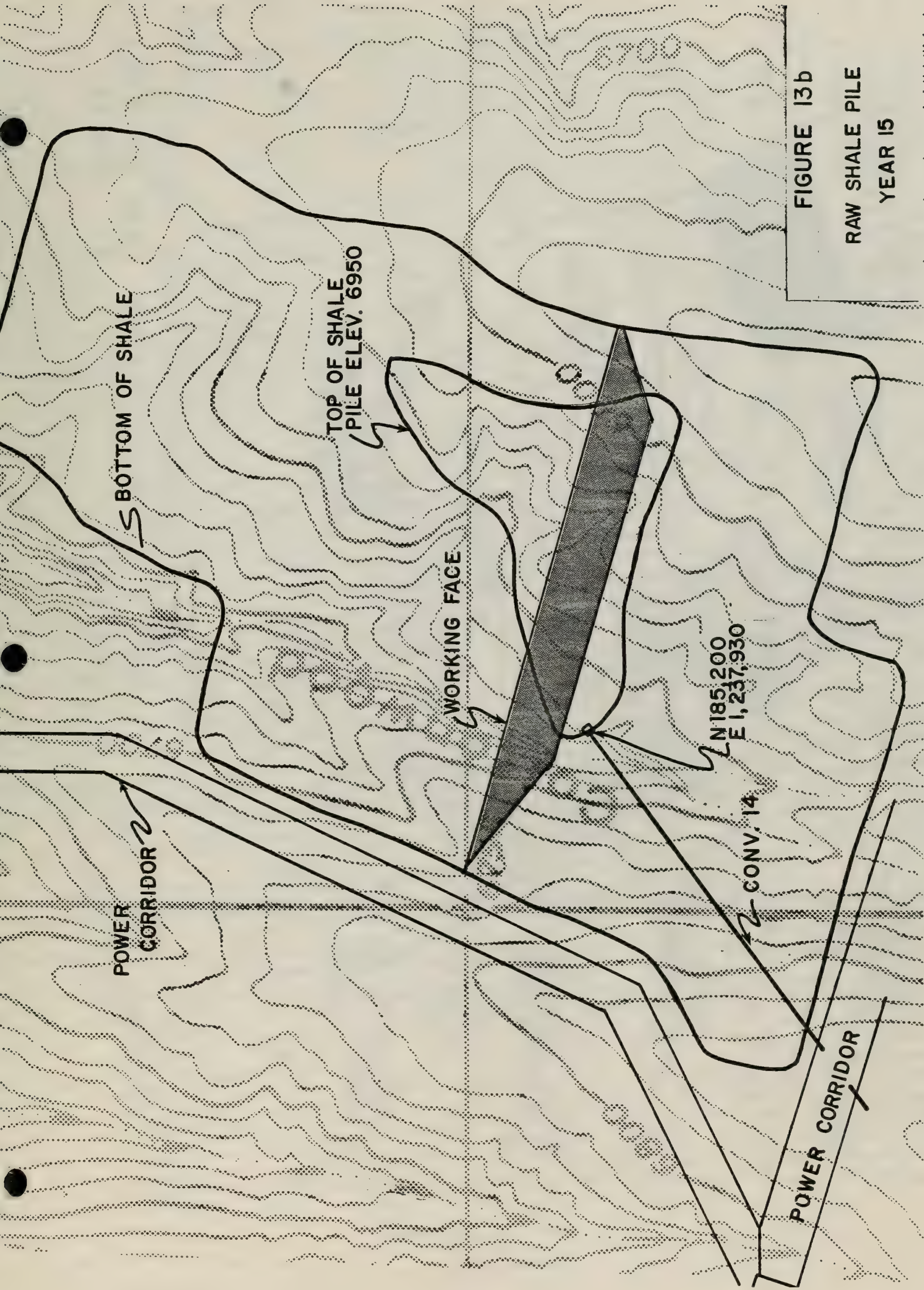


FIGURE 13b

RAW SHALE PILE

YEAR 15

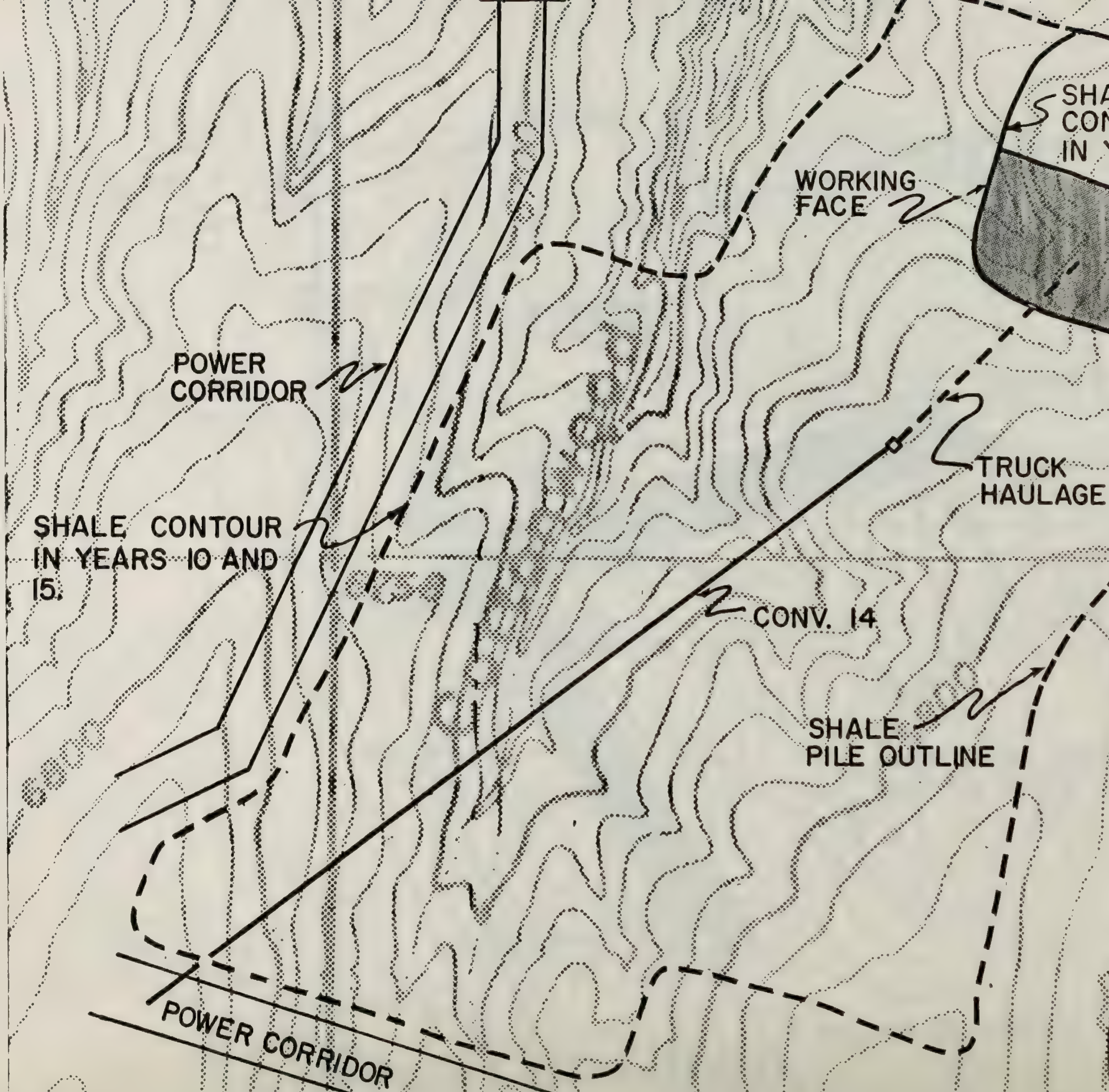


FIGURE 13c
RAW SHALE PILE
YEAR 25

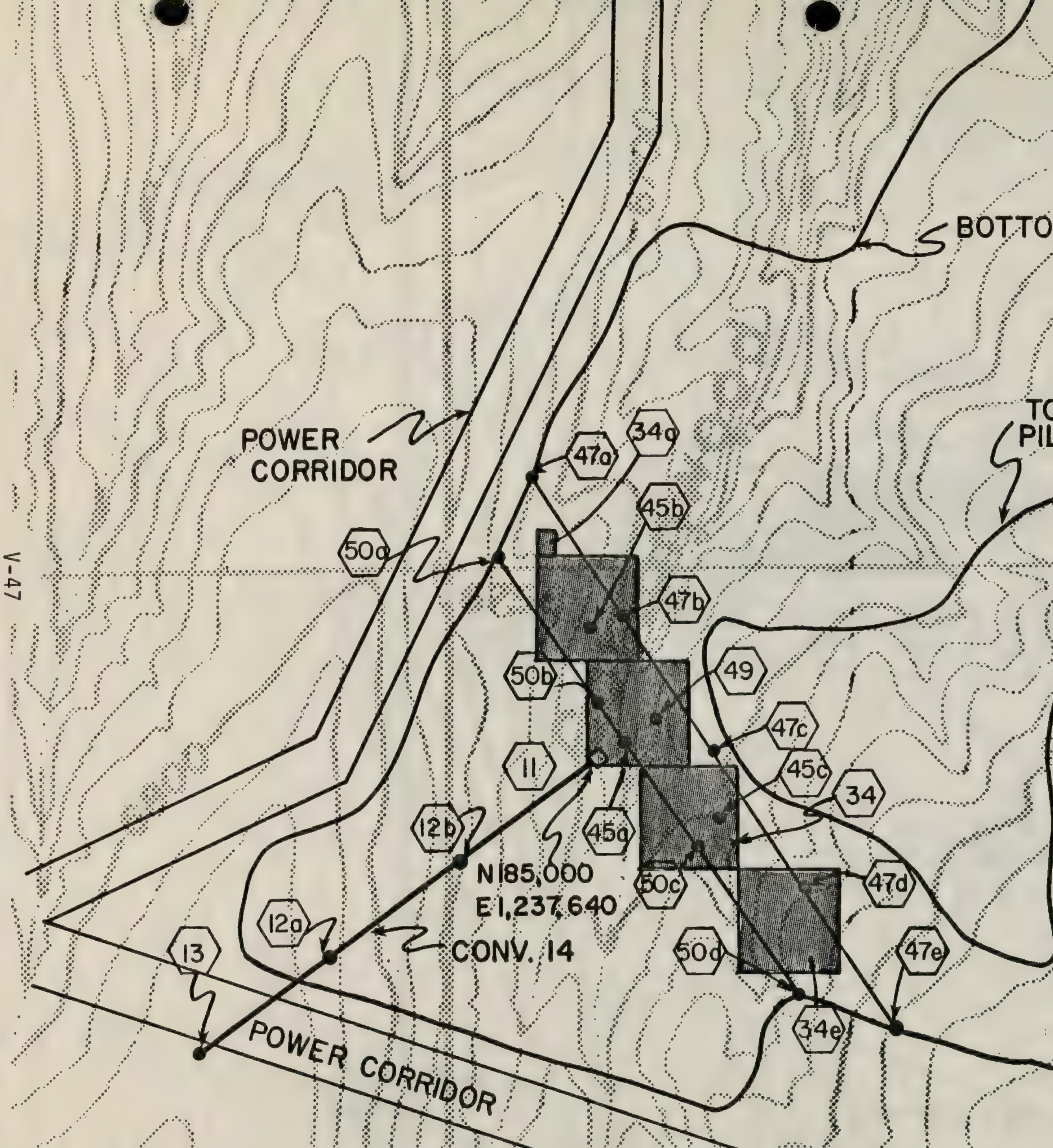


FIGURE 14a

COMPUTER REPRESENTATIONS OF RAW SHALE PILE TOPSOIL REMOVAL AND APPLICATION LOCATIONS, CONVEYOR 14 AND TRUCK HAULAGE ROUTES

YEAR 10

	LINE DESCRIPTION	DESCRIPTION
RAW SHALE PILE	45a,b,c	Vehicle Emission From Shale Pile to Conv. 14
5 BLOCKS	47a - e	Topsoil Dumping at Raw Shale Pile
SOURCES 34a-34e	49(Point)	Vehicle Emissions Over Shale Pile
	50a-50d	Topsoil Removal at Shale Pile

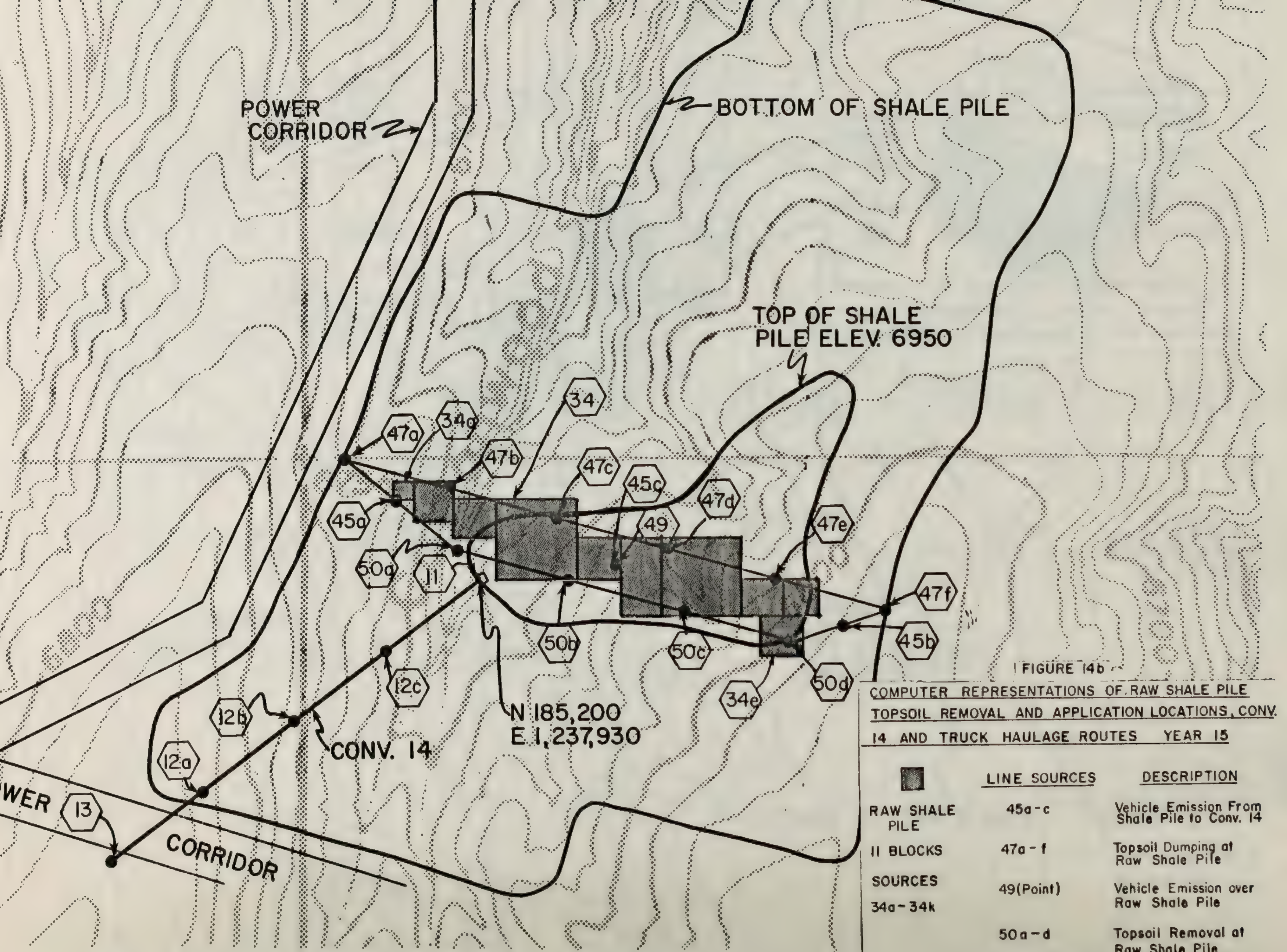


FIGURE 14b

COMPUTER REPRESENTATIONS OF RAW SHALE PILE TOPSOIL REMOVAL AND APPLICATION LOCATIONS, CONV. 14 AND TRUCK HAULAGE ROUTES YEAR 15

	LINE SOURCES	DESCRIPTION
RAW SHALE PILE	45a - c	Vehicle Emission From Shale Pile to Conv. 14
11 BLOCKS	47a - f	Topsoil Dumping at Raw Shale Pile
SOURCES 34a - 34k	49(Point)	Vehicle Emission over Raw Shale Pile
	50a - d	Topsoil Removal at Raw Shale Pile

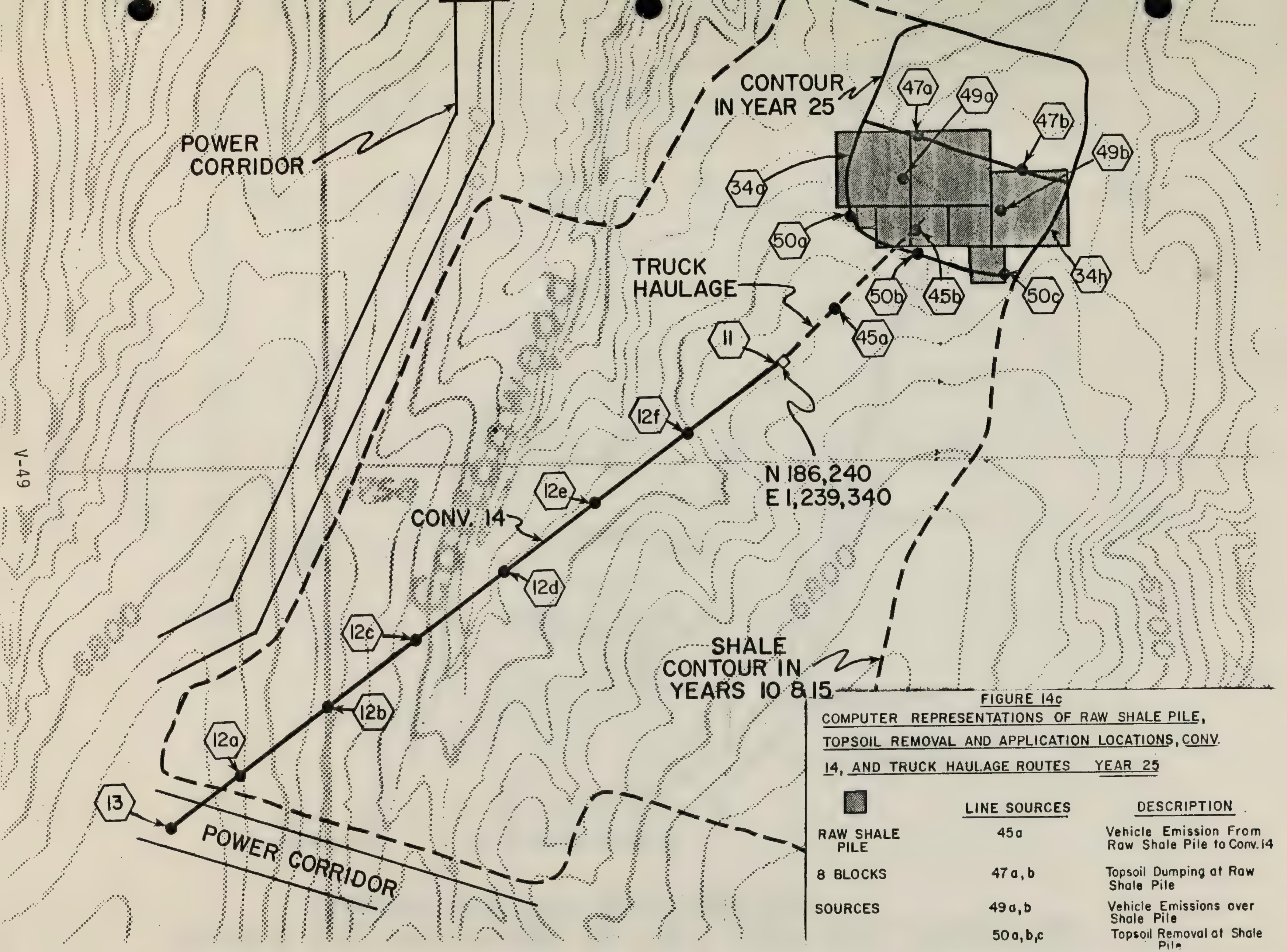
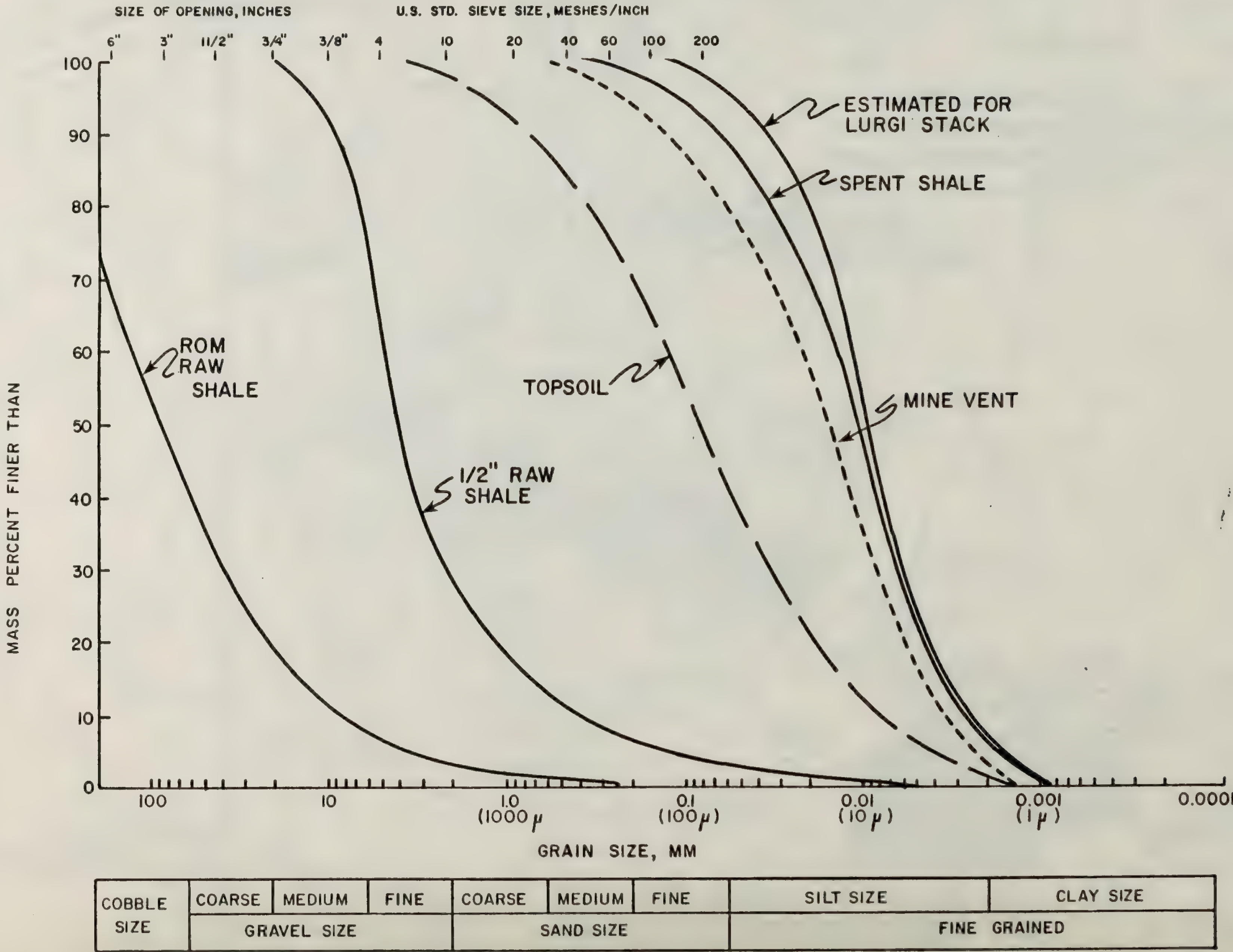


FIGURE 14c

COMPUTER REPRESENTATIONS OF RAW SHALE PILE, TOPSOIL REMOVAL AND APPLICATION LOCATIONS, CONV. 14, AND TRUCK HAULAGE ROUTES YEAR 25

	LINE SOURCES	DESCRIPTION
RAW SHALE PILE	45a	Vehicle Emission From Raw Shale Pile to Conv. 14
8 BLOCKS	47a, b	Topsoil Dumping at Raw Shale Pile
SOURCES	49a, b	Vehicle Emissions over Shale Pile
	50a, b, c	Topsoil Removal at Shale Pile

FIGURE 15. SIZE DISTRIBUTIONS FOR RAW & SPENT SHALE, TOPSOIL MINE EMISSIONS AND LURGI STACK EMISSIONS.



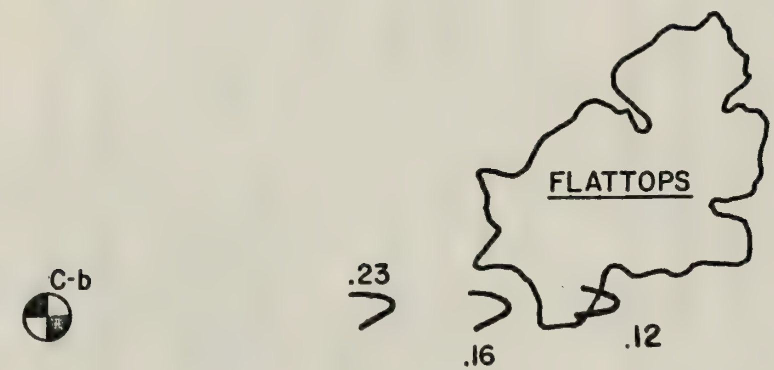


FIGURE 16
CLASS I 24-HR. TSP CONCENTRATIONS
(ug/m^3)
E STABILITY 10^hW WIND

6.2.1.2 Class II

With regard to particulates, as previously stated, location and extent of the shale piles change with time. Pile configurations in years 10, 15 and 25 were modeled with the result that those for year 25 yielded the highest ground level concentrations. It is to be further recalled that the emission factor for the shale piles is wind-speed dependent; i.e., shale pile emissions from wind erosion exist only when wind speed is in excess of 5.4 m/s (12 mph) with utilization of the EPA approved emissions formula.

In the initial screening process short-term (24-hour) TSP concentrations for worst and second-worst-case conditions at a 24-hour wind direction persistence resulted in high concentrations. A refined model version utilizing dry deposition was then run. Twenty-four hour resulting concentrations are as follows:

Worst Case - 6-hr persistence of SSW winds for F Stability @ 0.9 m/s yielded 41 ug/m^3;

Second Worst Case - 24-hr persistence of SSW winds for D Stability @ 10.8 m/s yielded 27 ug/m^3.

The second-worst case yielded 27 ug/m^3 compared to the standard of 37 ug/m^3. Isopleths for this (governing) case are presented on Figure 17. Isopleths for the annual case as obtained from the inital screening mode using the basic Valley Model are presented on Figure 18. Maximum off-tract concentrations are 10 ug/m^3 compared to the Class II standard of 19 ug/m^3.

Demonstration of compliance with PSD increments is summarized on Table 1.

6.2.2 Compliance with NAAQS

The baseline value for particulates (Section 3.2) is 13 ug/m^3. This value is added to the second-highest modeled increments to demonstrate compliance with NAAQS as shown in Table 2.

6.2.3 Compliance with State of Colorado Standards

These ambient standards are the same as the NAAQS.

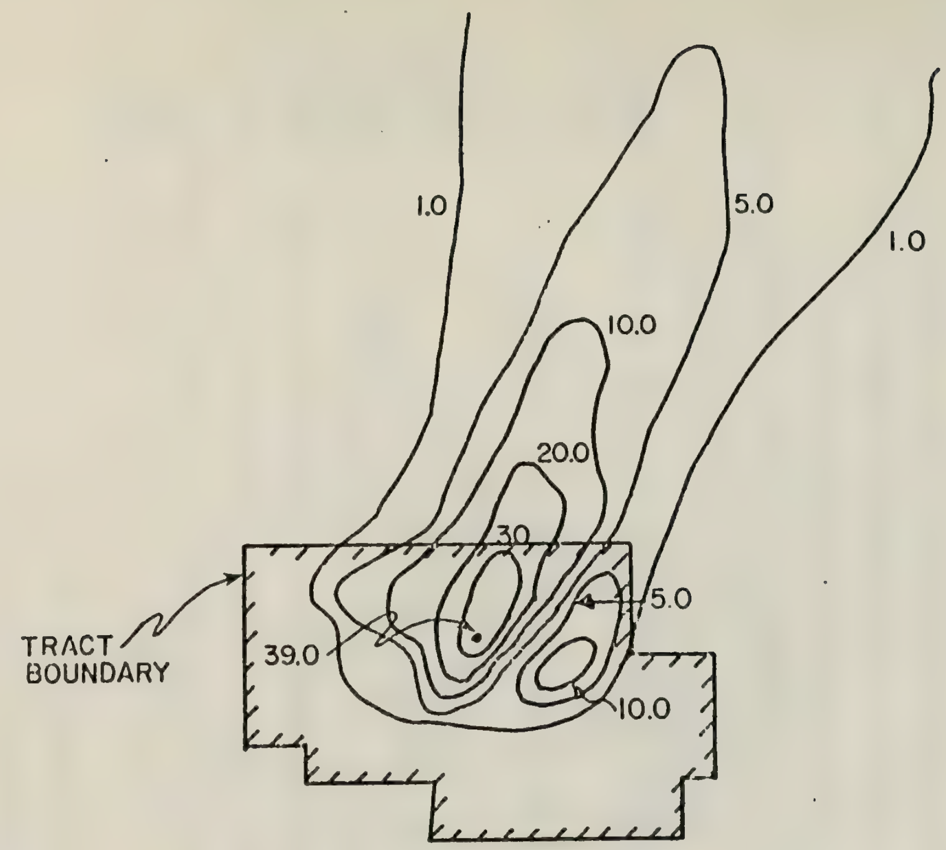


FIGURE 17

CLASS II 24-HR. PARTICULATES CONCENTRATIONS

JOB 6276 & JOB 6279
D STAB. 24-HR SSW AT 10.8 m/s

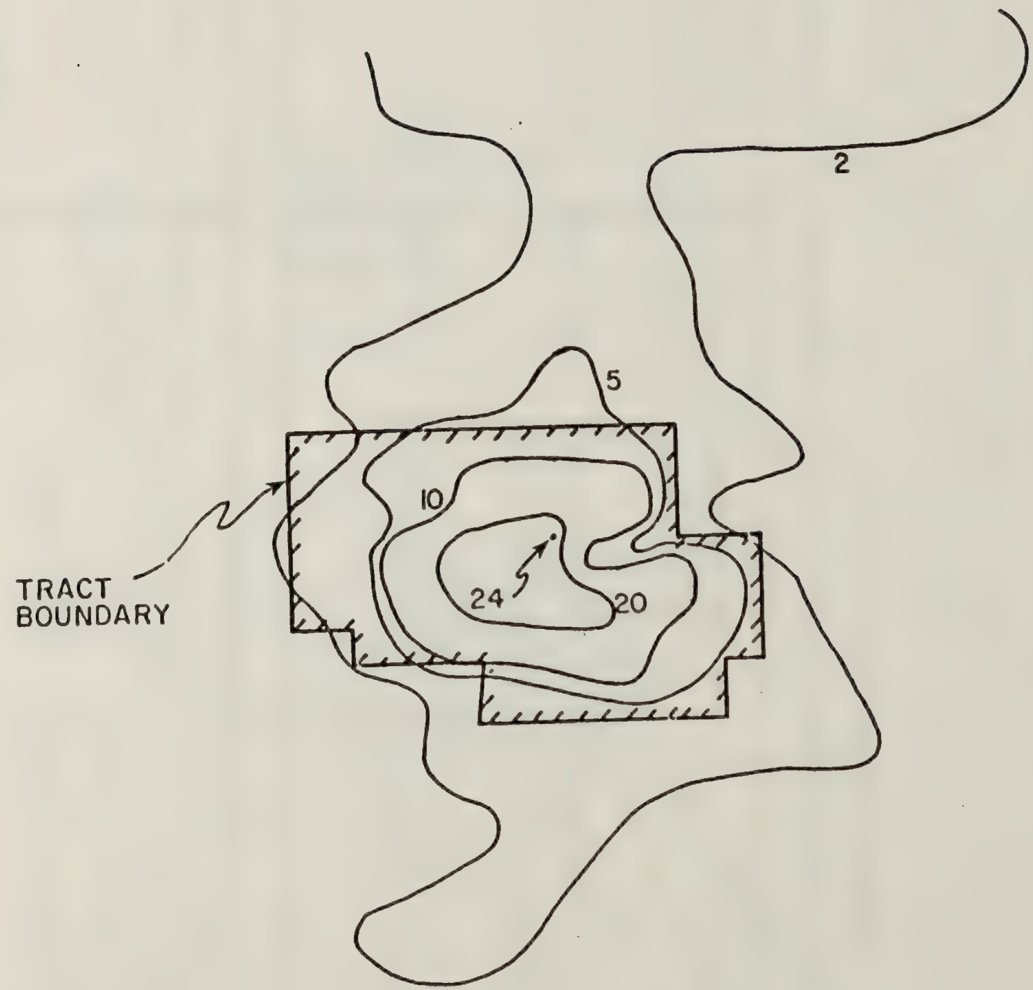


FIGURE 18
CLASS II ANNUAL PARTICULATES
CONCENTRATIONS
(ug / m3)

JOB 8502

7.0 Other Modeling

Three topics are included here: demonstration of compliance with NAAQS for CO and NO_2, effects from secondary emissions sources and approximate regional modeling.

7.1 NAAQS Compliance for CO and NO_2

One- and eight-hour CO concentrations were run for Cases 15, 17, 18 of Table 5 and yield peak off-tract concentrations of 858 and 479 ug/m^3 respectively. When baseline values are added to these values the sums are well below the Federal standards of 40,000 and 10,000 ug/m^3 respectively, and compliance is demonstrated as shown on Table 2.

Annual NO_2 concentrations were run (as NO_x) yielding peak off-tract concentrations of 71 ug/m^3 for C.B. sources. The Federal standard of 100 ug/m^3 is as shown on Table 2. Isopleths are shown on Figure 19. When the baseline value of 2 is added to 71, the value of 73 is well below the NAAQS standard of 100 ug/m^3 and compliance is demonstrated as shown in Table 2.

7.2 Effects from Secondary Emissions Sources

7.2.1 On PSD Increments

Currently permitted primary sources and secondary sources such as those emissions from towns and traffic which are due to presence of permitted primary sources all of which are within a prescribed impact radius of the C-b Tract are potentially chargeable to the PSD increment of C.B. This is true only if contributions of these sources affect the Class II increment at the point of maximum ground level ambient concentration, or if these sources affect the Class I increment at the border of the Flattops Wilderness area.

7.2.1.1 Other Currently-Permitted Primary Sources

Currently permitted primary sources in the area are:

Source	Size	Distance From C.B. mi	(km)
Colony	47,000 bbls/day	13	(20.9)
Union	9,000 bbls/day	12	(19.3)
C-a	1,000 bbls/day	18	(29.0)
C.B.	5,000 bbls/day	0	(0)

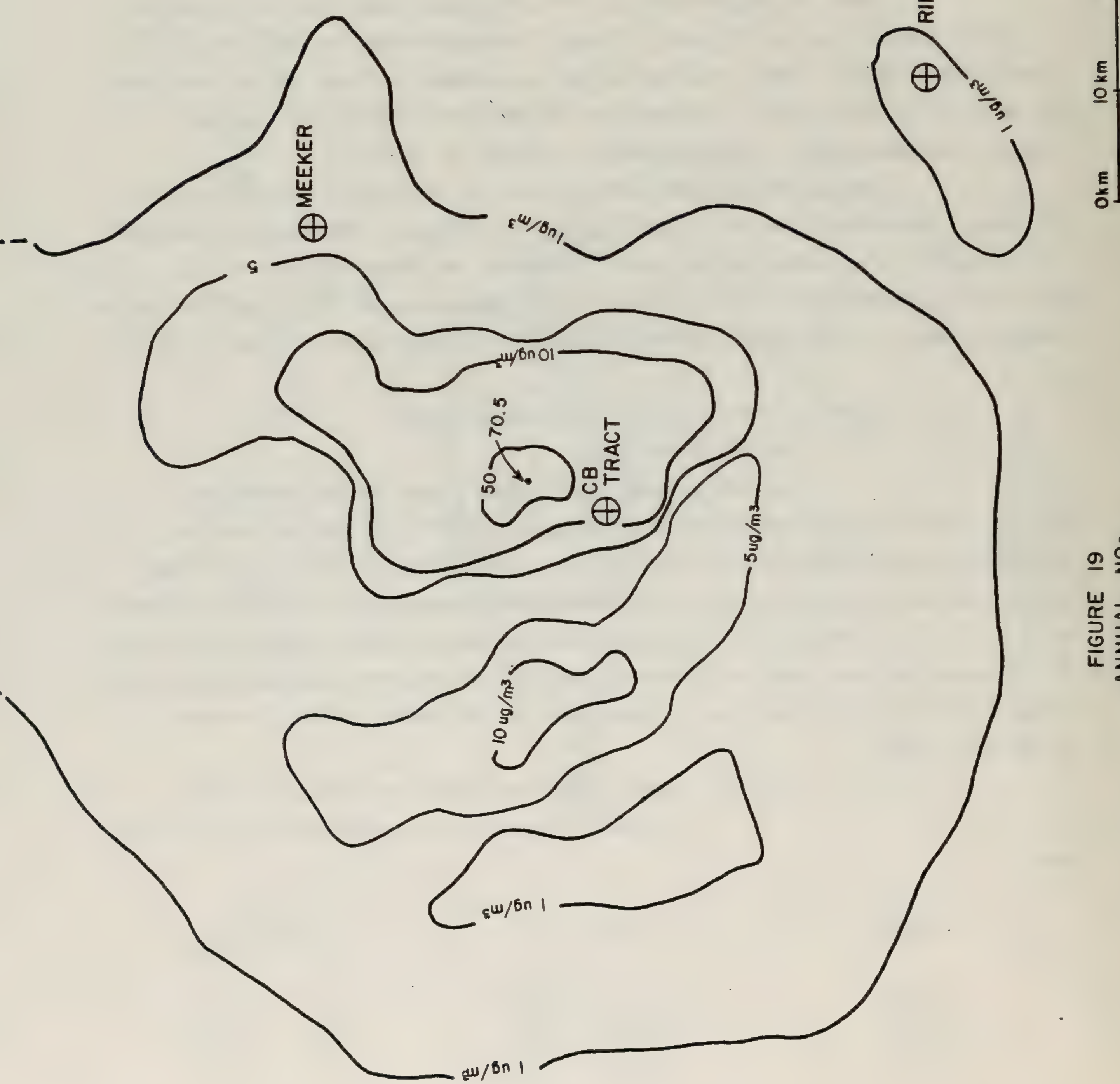


FIGURE 19
ANNUAL NO_2
CONCENTRATIONS
JOB 3940

Occidental's Logan Wash facility and Paraho's facility are test facilities operated on a temporary basis and are not further considered. Towns in the vicinity include Rifle, Meeker, Rangely, Battlement Mesa, De Beque, Parachute, and Silt.

Significance levels for air quality impacts are shown on Table 11 for various pollutants and averaging times. Using annual SO_2 as an example, the significance level for this case is 1 ug/m^3; the 1 ug/m^3 isopleth for C.B. sources is generated as on Figure 20. A circle centered at C.B. tangent to the farthest extremity of the 1 ug/m^3 isopleth is called the impact radius. Permitted sources other than C.B. and secondary sources within this radius should be modeled for potential effects on increment consumption for this pollutant (SO_2) and averaging time (annual). The following impact radii have been established:

Pollutant	Averaging Time	Significance Level Isopleth Shown on Figure	Impact Radius Mi (km)
TSP	24-hr	17	6.4 (10.3)
SO_2	3-hr	8	7.5 (12)
SO_2	24-hr	7	15.4 (24.8)
TSP	Annual	21	17.7 (28.5)
SO_2	Annual	20	29.2 (47)
NO_2	Annual	19	41.6 (67)

These are shown on Figure 22.

Results for the effects of permitted primary sources are as follows: for Class I the maximum impact locations all occur at the east-southeastern border of Flattops and are therefore linearly additive. These are indicated on Table 12.

For Class II, results are dependent on the impact radius and on the location of the maximum impact point.

1) Annual SO_2 - Permitted primary sources within the 47 km impact radius are Union, Colony, C-a, and C.B. The location of the maximum impact point for the present application is approximately 8 km from the origin in a NNE direction. Union, Colony, and C-a contribute negligible increments at this location. C.B.'s permitted facility contributes 0.1 ug/m^3 at this location.

2) Annual TSP - In order of decreasing impact radius, this condition is next and admits the same four sources at an impact

TABLE 11

SIGNIFICANCE LEVELS FOR AIR QUALITY IMPACTS

Pollutant	Averaging time				
	Annual, ug/m^3	24-Hour, ug/m^3	8-Hour ug/m^3	3-Hour ug/m^3	1-Hour ug/m^3
SO_2	1	5	-	25	-
TSP	1	5	-	-	-
NO_2	1	-	-	-	-
CO	-	-	0.5	-	2

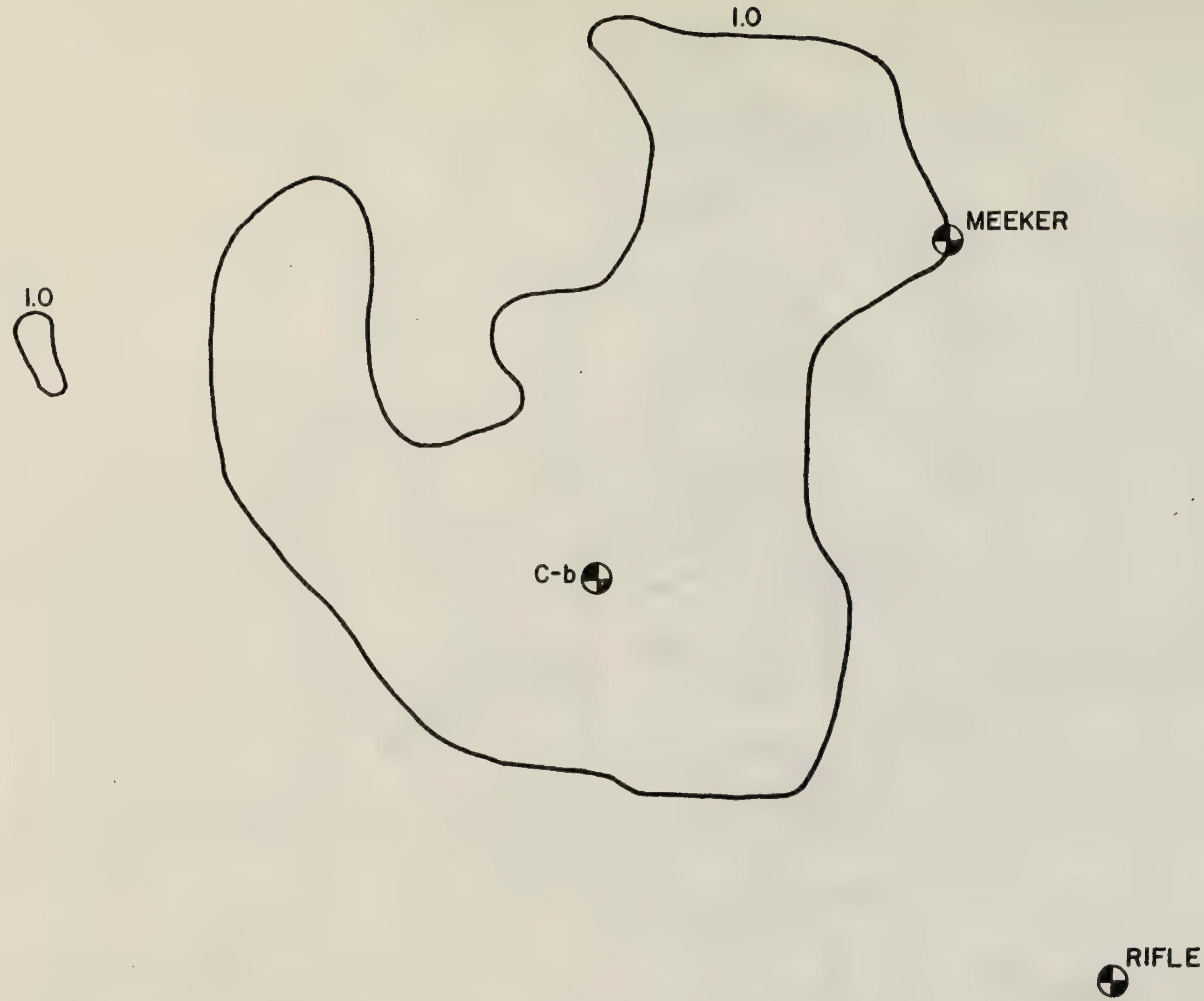


FIGURE 20
ANNUAL SO_2 CONCENTRATIONS
SECONDARY EFFECTS
(ug/m^3)
JOB 9823

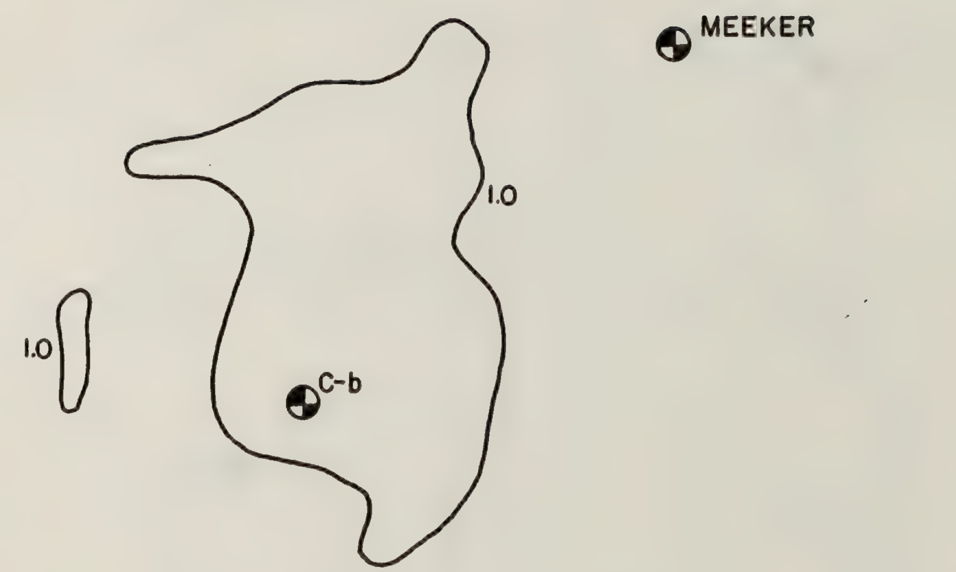


FIGURE 21
ANNUAL PARTICULATES
SECONDARY EFFECTS
(ug / m^3)
JOB 784

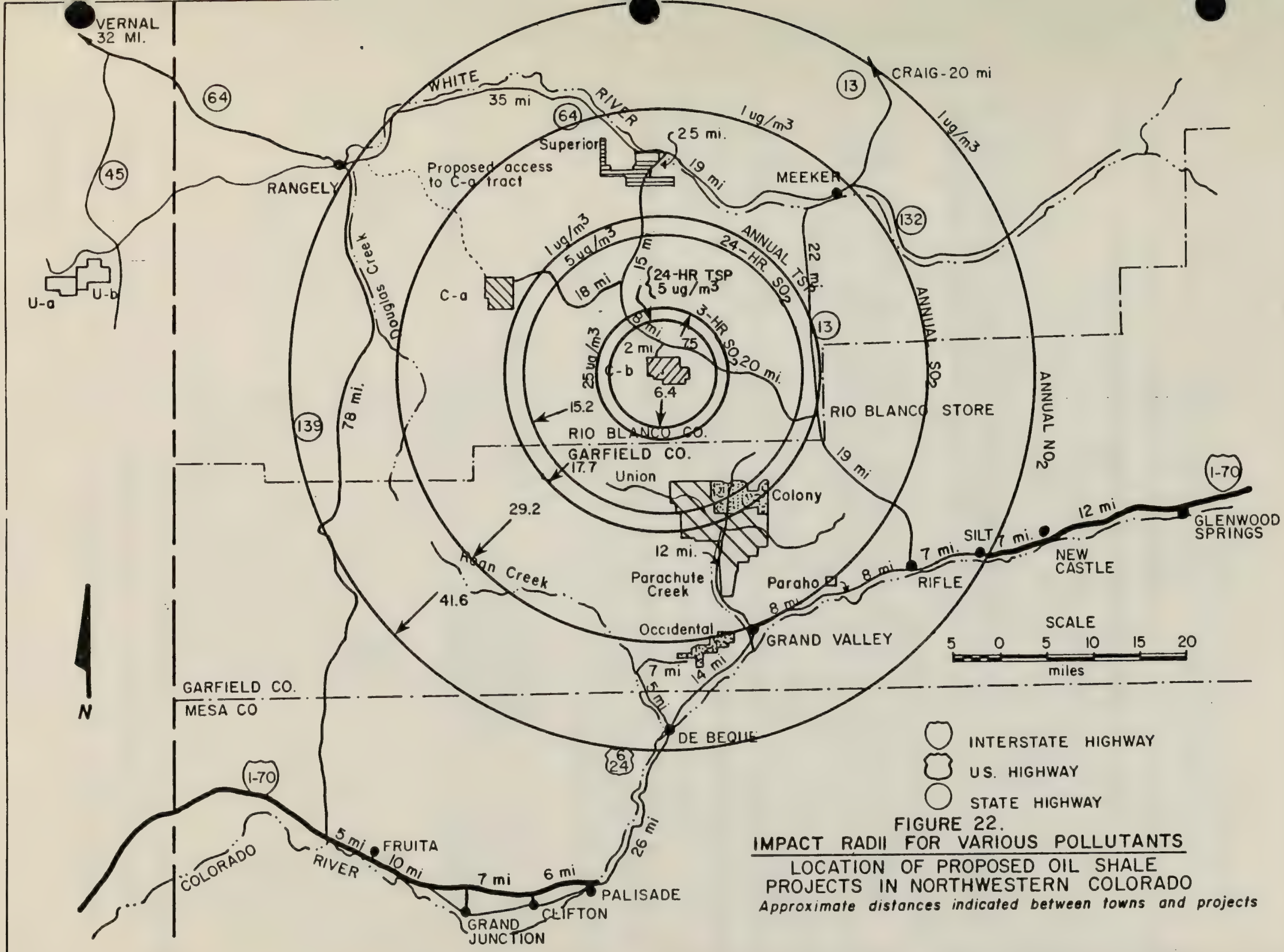


FIGURE 22.
IMPACT RADII FOR VARIOUS POLLUTANTS
LOCATION OF PROPOSED OIL SHALE PROJECTS IN NORTHWESTERN COLORADO
Approximate distances indicated between towns and projects

TABLE 12

EFFECTS OF PERMITTED PRIMARY SOURCES ON CLASS I AREA*

(Flattops)

Pollutant	Impact from Each Source (ug/m^3)				Total (ug/m^3)
	Colony	Union	C-a	C.B.**	
SO_2					
Annual	<0.05	0.001	<0.02	<0.01	<0.081
24-hr	<0.05	0.01	0.3	<0.1	<0.46
3-hr	0	0.06	0.8	0.2	1.06
TSP					
Annual	~0	<0.001	<0.01	~0	<0.011
24-hr	0.01	0	0.1	~0	<0.11

*These are linearly additive since they occur at south-southeastern border of Flattops.

**5000 bbl/day permitted C.B.

radius of 28.5 km. The maximum impact location is on the northern tract boundary in the NNE direction from the origin. Union, Colony, and C-a contribute negligible increments at this location. C.B.'s permitted facility contributes approximately 3.5 ug/m^3 (80 acres of shale pile).

3) 24-hr SO_2 - The impact radius is 24.8 km and includes permitted sources, Union, Colony, and C.B. (but not C-a). Point of maximum impact occurs on the tract boundary in a NNW direction. Union and Colony contribute negligible increments at this location. C.B.'s permitted facility contributes 0.0 ug/m^3 at this location.

4) 3-hr SO_2 - The impact radius is 12 km and C.B.'s permitted facility is the only source therein. The maximum impact location is on the northern tract boundary in a NNW direction from the origin. C.B.'s permitted facility contributes 0.0 at this location.

5) 24-hr TSP - The impact radius is 10.3 km and C.B.'s permitted facility is the only source therein. The maximum impact location is on the northern edge of the tract boundary in a NNE direction from the origin. C.B.'s permitted facility contributes 4.4 ug/m^3 at this location.

In summary the effects of permitted facilities on the C.B. Class II increment are:

Pollutant	PSD Increment Consumed by C.B. Alone (ug/m^3)	PSD Increment Consumed by Other Permited Facilities (ug/m^3)	Total PSD Increment Consumed (ug/m^3)
SO_2			
Annual	15.6	0.1	15.7
24-hr	73	0.0	73
3-hr	303	0.0	303
TSP			
Annual	10	3.5	13.5
24-hr	29	4.4	33.4

7.2.1.2 Secondary Sources

For the secondary effects study, as depicted on Figure 23, in addition to the permitted primary sources potential secondary sources were assumed to exist in neighboring towns and as traffic along the following road segments:

SCENARIO 1

ROAD SEGMENT	EMISSION (g/mi/s) SO$_2$	TSP
①	0.014	0.007
②	0.002	0.002
③	0.009	0.005

EMISSION SOURCE	EMISSION (g/s) A RIFLE SO$_2$	TSP	B MEEKER SO$_2$	TSP
VEHICLE TRAFFIC	0.37	0.70	0.16	0.29
TRAIN	0.90	0.40	–	–
HOME Htg.	0.01	0.23	0.004	0.10
TOTAL	1.28	1.33	0.16	0.39

SCENARIO 2

ROAD SEGMENT	EMISSION (g/mi/s) SO$_2$	TSP
①	0.024	0.017
②	0.030	0.024
③	0.032	0.025

EMISSION SOURCE	EMISSION (g/s) A RIFLE SO$_2$	TSP	B MEEKER SO$_2$	TSP
VEHICLE TRAFFIC	0.64	1.22	0.38	0.73
TRAIN	0.90	0.40	–	–
HOME Htg.	0.01	0.40	0.01	0.23
TOTAL	1.55	2.02	0.39	0.96

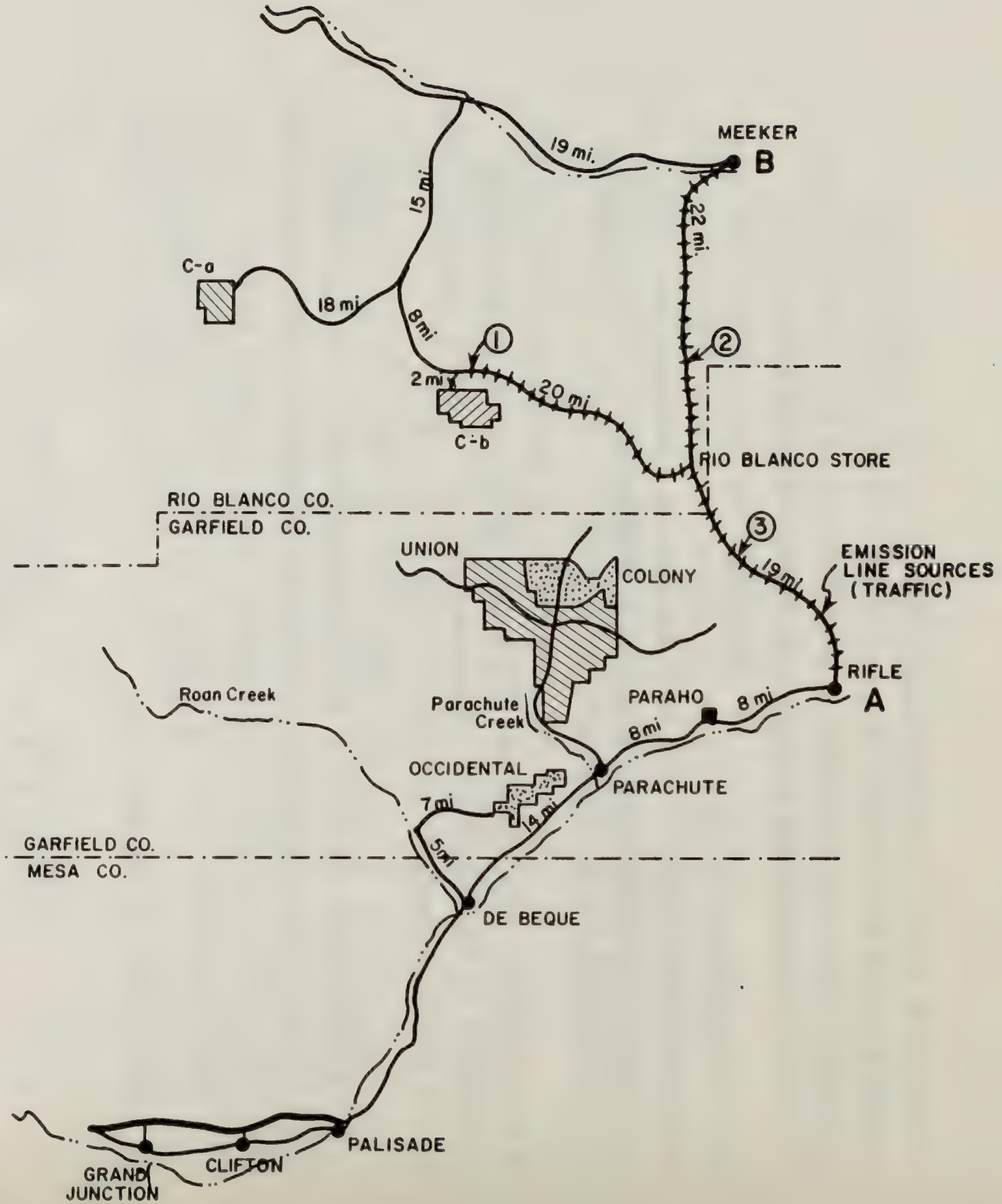


FIGURE 23. SECONDARY EMISSION SOURCES

Segment 1 - C-b Tract to Piceance Creek Road (PC) then along the road to Rio Blanco Store (RB);

2 - From RB to Meeker;

3 - From RB to Rifle.

Town of Rifle emissions consisted of sources due to vehicle traffic, trains, and house heating. Meeker emissions consisted of vehicle traffic and house heating. Secondary emission factors are contained in Appendix 10.0 for a case called Scenario 1. A second scenario designated here as Scenario 2 incorporates effects of increased regional population levels as estimated in the Colorado West Transportation Plan(1) and the Colorado West Population Projections(2) as contained in Appendix 13.0. Emissions were ratioed up from Scenario 1 on the basis of population increases. Scenario 1 includes secondary effects of C.B. operations on the neighboring region. Scenario 2 adds secondary effects of all existing permitted facilities to the secondary effects of Scenario 1. Figure 23 depicts SO_2 and TSP secondary emissions; Table 13 gives NO_x and CO emissions. Initial screening indicated that only Rifle, Meeker and the above road segments were of sufficient magnitude for further consideration as secondary sources.

Regarding PSD increment consumption only the annual SO_2 impact radius intersects Meeker; no impact circle intersects Rifle. Therefore Rifle was eliminated as a secondary emission source. The annual SO_2 case also envelops about half of the road from C.B. to Rio Blanco store; thus both Meeker and the nearby road were modeled as secondary sources. A Meeker-centered annual SO_2 run using C.B. meteorology (since Meeker has none available) resulted in a maximum concentration very close to Meeker of less than 1.0 ug/m^3 for both Scenarios 1 & 2 so Meeker itself has no effect on maximum concentrations near the Tract. For both Scenarios 1 & 2 effects at Flattops are near zero. To the nearest 0.1 ug/m^3 secondary effects of the road on primary concentrations near C.B. and of both scenarios are summarized on Table 14.

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(1) This reference year is 2000. It assumes 205,000 BPD shale oil production and 19 million tons/yr coal production.

(2) The reference year is 1990. It utilizes currently projected coal and oil shale development.

TABLE 13

Secondary NO_x & CO Emissions

Scenario	Item	NO_x	CO (1-Hr)
1	Town of Rifle (gm/sec)		
	Vehicle Traffic	5.46	46.3
	Train	5.83	-
	Home Heating	1.22	0.30
	Total	12.51	46.6
	Town of Meeker (gm/sec)		
	Vehicle Traffic	2.27	10.87
	Train	-	-
	Home Heating	0.50	0.13
	Total	2.77	11.0
	Road Segment (gm/sec/mi)		
	1	0.033	0.010
	2	0.004	0.001
	3	0.023	0.008
2	Town of Rifle (gm/sec)		
	Vehicle Traffic	9.46	44.77
	Train	5.83	-
	Home Heating	2.11	0.53
	Total	17.40	45.30
	Town of Meeker (gm/sec)		
	Vehicle Traffic	5.61	26.86
	Train	-	-
	Home Heating	1.25	0.32
	Total	6.85	27.18
	Road Segment (gm/sec/mi)		
	1	0.110	0.372
	2	0.162	0.594
	3	0.164	0.580

TABLE 14

EFFECTS OF SECONDARY SOURCES

(a) On PSD Increments

Scenario	Class	Case	Primary Concentration (ug/m^3)	Secondary Sources Concentration (ug/m^3)	Location
1	I	24-Hr SO_2	<0.01	<0.01	Flattops
		Annual SO_2	0.06	<0.02	
		24-Hr TSP	0.15	<0.01	
		Annual TSP	0.03	<0.01	
2	I	24-Hr SO_2	<0.01	<0.01	Flattops
		Annual SO_2	0.06	<0.02	
		24-Hr TSP	0.15	0.02	
		Annual TSP	0.03	<0.01	
1	II	24-Hr SO_2	73	0.0	Max. Class II Concentration Point
		Annual SO_2	15.6	0.0	
		24-Hr TSP	27	0.1	
		Annual TSP	10	0.0	
2	II	24-Hr SO_2	73	0.0	Max. Class II Concentration Point
		Annual SO_2	15.6	0.0	
		24-Hr TSP	21	0.0	
		Annual TSP	10	0.0	

(b) On Max. CO & NO_x Concentrations

There were no effects on CO & NOX at the point of maximum off-tract concentrations.

In addition to the effects of secondary sources on SO_2 and TSP, their effects on NO_x and CO were investigated. NO_x has its point of maximum concentrations NNE of the tract at a distance of 8 km. At this location all roads had negligible effects. C.B.'s permitted facility adds 2.8 ug/m^3 there. No effects of other sources on CO were found.

7.3 Regional Basin Impacts

An approximate SO_2 analysis has been made using the Valley Model for the major oil-shale sources in the Piceance Basin in this time period to determine their combined effects on Class I areas. These sources include:

C.B. @	117,000 bbls/day
C-a @	76,000 bbls/day
Union @	150,000 bbls/day
Colony @	47,000 bbls/day
Unspecified Source @	200,000 bbls/day
TOTAL	590,000 bbls/day

Present small permitted sources have been ignored.

Emission source locations are shown on Figure 24; emission source strengths and stack characteristics are presented in Table 15. Assumptions include:

1. One stack summarizes each facility.
2. Emissions are prorated on basis of C.B. by bbl/day of output; Colony is ratioed by 98% BACT.
3. C.B. annual meteorology has been assumed to apply.

Concentrations for this annual case are approximately 1.0 ug/m^3 at the Flattops boundary as shown on Figure 25. These results are approximate at best at 57 km from C.B.

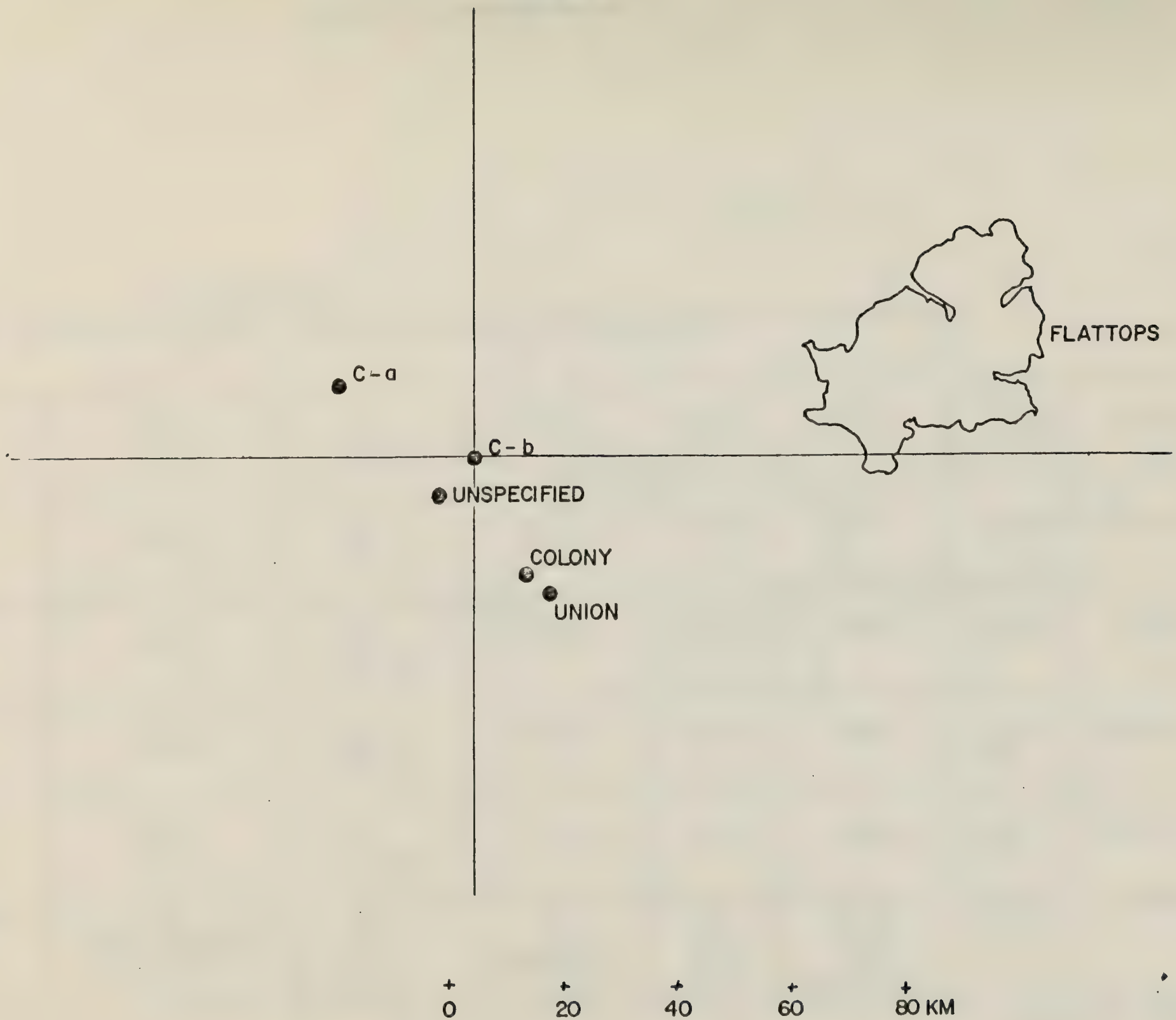


Figure 24
REGIONAL STUDY
SO_2 EMISSION SOURCE LOCATIONS

TABLE 15

Emission Inputs and Stack Characteristics for Regional Case

Run Group Regional

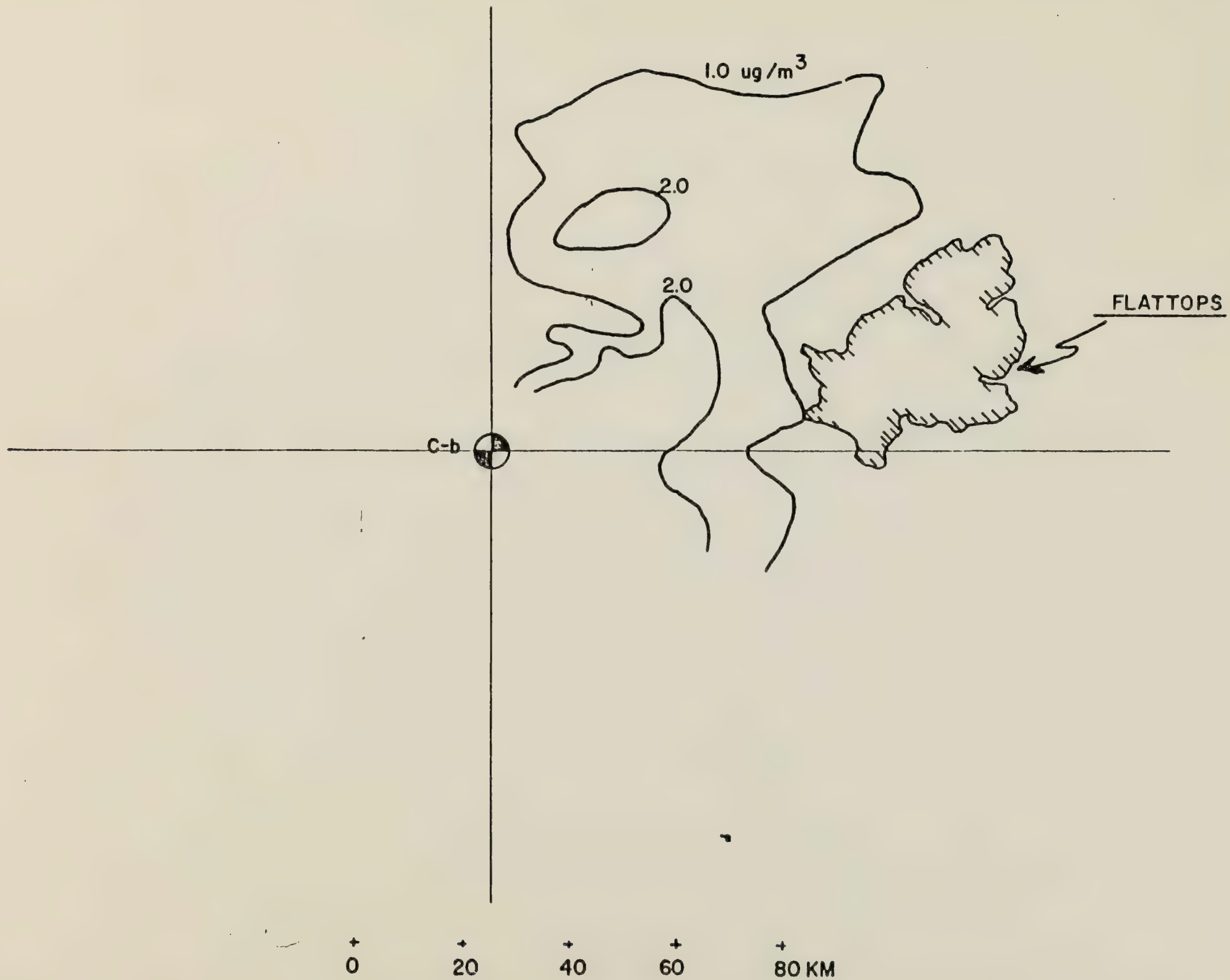
Source Identification	Emissions lb/hr (gm/sec) SO_2	Stack Height (m) Ft.	Stack Diameter (m) Ft.	Exit Temp. (^oK) ^oF	Actual Vol. Flow (m^3/s) WACFM	Exit Speed	Remarks
Tract C-b	(226)	(152.40) 500	(11.95)	(357)	(4100)	120 (36.6)	105,000 bbl/day*
Unspecified	(452)	(152.40) 500	(16.9)	(357)	(8200)	120 (36.6)	200,000 bbl/day
Tract C-a	(159)	(152.40) 500	(10.2)	(357)	(2968)	120 (36.6)	76,000 bbl/day
Union	(227)	(76.2) 250	(17.4)	(450)	(5856)	80 (24.4)	150,000 bbl/day
Colony	(40)	(76.2) 250	(12.8)	(450)	(3124)	80 (24.4)	47,000 bbl/day

*12,000 bbl/day phosam unit has been subtracted off for purposes of ratioing emissions for others to those of C.B. on a bbl/day basis.

Figure 25

REGIONAL STUD

ANNUAL SO_2 CONCENTRATIONS



VI ADD. IMPACT ANALYSIS

VI.

ADDITIONAL IMPACT ANALYSIS

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TABLES

VI. ADDITIONAL IMPACT ANALYSIS

1.0 Growth Analysis

The air quality impact from the project includes sources of emissions not limited to the Tract C-b operation. These sources are associated with the necessary movement of people and materials to and from the Tract, the population increases in surrounding cities resulting from the employees families and needed services support, and from additonal railroad activity associated with the rail siding near Rifle.

1.1 Socioeconomic Analysis

The basis upon which the off-Tract emissions are calculated, is the socioeconomic analysis. This study was done as a requirement of the submittal for the DOE Alternate Fuels Proposal Loan Guarantee Program. The complete study is found in Appendix 9.0. It is based on the latest development philosophy and includes the manpower curves, anticipated population increases in the various cities, and mitigative measures to be taken to minimize the adverse effects of growth caused by the C.B. project.

1.2 Emissions from Off-Tract Activities

1.2.1 Introduction

Rocky Mountain Division, the Pace Company Consultants and Engineers, Inc., at the request of Cathedral Bluffs Shale Oil Company, has quantified the emissions associated with off-Tract vehicle traffic, and secondary impacts from population growth resulting from the C.B. project. This analysis is based on the earlier socioeconomic study, Appendix 9.0. The emissions are summarized and the basis for their derivation specified. To ensure acceptance by the reviewing agencies, the regional office of the Environmental Protection Agency was contacted to verify the validity of the methods being utilized. The emission factors used for the various sources are tabulated in Appendix 10.0.

1.2.2 Summary

Two sets of emission are shown for impacts of the Cathedral Bluffs project. The first set (shown in Tables VI-1 and VI-2) are emissions that result from off-Tract vehicle traffic associated with plant operations. The emission factors used were developed from an EPA computer program and represent the most up-to-date factors available.

The second set of emissions is a sum of the discharges resulting from the increased population, termed secondary impacts, in towns

such as Meeker, Rifle, and Silt. (Shown in Tables VI-3 and VI-4). The population figures consider not only the plant work force, but also the service sector personnel and their families. These sources result from emissions from their vehicles, home heating, and a railway siding near Rifle. The emissions are utilized in the Air Diffusion Model (Section V) to determine any impact on the increments and to establish the isopleths necessary to determine if the on-tract and off-tract emissions would intersect at any point in their dispersion patterns. When the off-tract emissions intersect the on-Tract emissions, they are modeled against the increment.

TABLE VI-I
EMISSIONS FROM OFF-TRACT VEHICLES

Vehicle Type	Sulfur Dioxide (lb/day)	Particulate (lb/day)	Nitrogen Oxides (lb/day)	Hydrocarbons (lb/day)
Diesel	94	43	241	49
Gasoline	4	7	52	28
TOTAL	98	50	293	77

TABLE VI-2
CARBON MONOXIDE EMISSIONS FROM OFF-TRACT VEHICLES
(pounds per hour)

	Vehicle Type		
Time	Diesel	Gas	Total
0100	6	3	9
0200	6	3	9
0300	6	3	9
0400	6	3	9
0500	6	3	9
0600	6	3	9
0700	45	17	62
0800	51	25	76
0900	12	11	23
1000	12	11	23
1100	12	11	23
1200	12	11	23
1300	12	11	23
1400	12	11	23
1500	51	22	73
1600	51	22	73
1700	12	11	23
1800	12	11	23
1900	12	11	23
2000	6	3	9
2100	6	3	9
2200	6	3	9
2300	23	3	26
2400	23	3	26

TABLE VI-3
EMISSIONS FROM SECONDARY IMPACTS

Towns	Sulfur Dioxide (lb/day)	Particulates (lb/day)	Nitrogen Oxides (lb/day)	Hydrocarbons (lb/day)
Rifle	243	253	2,382	883
Meeker	30	74	528	251
Silt	12	29	211	100
Other Areas*	6	15	105	50

*Other Areas represent towns such as Rangely, Battlement, and Parachute.

TABLE VI-4
CARBON MONOXIDE EMISSIONS FROM SECONDARY IMPACTS
(pounds per hour)

	Town			
Time	Rifle	Meeker	Silt	Other Areas
0100	207	87	34	17
0200	207	87	34	17
0300	207	87	34	17
0400	207	87	34	17
0500	207	87	34	17
0600	207	87	34	17
0700	207	87	34	17
0800	207	87	34	17
0900	207	87	34	17
1000	207	87	34	17
1100	207	87	34	17
1200	207	87	34	17
1300	207	87	34	17
1400	207	87	34	17
1500	207	87	34	17
1600	207	87	34	17
1700	207	87	34	17
1800	207	87	34	17
1900	207	87	34	17
2000	207	87	34	17
2100	207	87	34	17
2200	207	87	34	17
2300	207	87	34	17
2400	207	87	34	17

2.2.3 Vehicles

The emissions from off-tract cars and trucks are based on the following vehicle numbers and types. The vehicle distribution and emissions were developed with the resultant assumptions: 1) FMC gas treating will be used requiring limestone, 2) 98% of the labor force will ride the

company-provided buses, 3) all available NH_3 will be liquified and sold as product, 4) explosives will be manufactured off-tract, 5) no private vehciles will be allowed on-tract, and 6) all gasoline vehicles will be new generation type with catalytic, or equivalent, control of exhaust emissions.

TABLE VI-5
Off-Tract Vehicles Entering and Leaving
The Site on a Daily Basis

A) Diesel Vehicles		
1) Employee Buses		85****
2) 20 Ton Limestone Trucks, 1000 T/D		50
3) Vendor Supply 40/D, 25% Diesel		10**
4) Explosives and primers		8**
5) Concrete and associated raw materials		25**
6) Ammonia product (liquefied)		18
7) Oxy Support		5**
8) Fuel Supply		4**
	TOTAL	205
B) Gasoline Vehicles		
1) @ 4430 employees approximately 3320/day, 2%=66 Assume two riders/vehicle		33*,***
2) Company vehicles		50
3) Vendor vehicles		30**
4) Support and Regulatory Agencies		15**
5) Sales representatives		20**
	TOTAL	148
	TOTAL OF BOTH A & B	353

* These will park at the tract boundary
** It is assumed that these will impact the site between the hours of 8:00 a.m. and 8:00 p.m. All others are assumed to be 24-hour operations.
*** These will only impact at morning and afternoon shift change.
**** Buses will impact the tract only at shift change.

The emissions are calculated using the number of vehicles, the trip mileage, and a quantity known as the emission factor. The emission factor relates the quantity of emissions such as carbon monoxide, or sulfur dioxide to the number of miles driven. The emission factor is dependent on the age and type of vehicle, the driving speed, the air temperature, the engine temperature, and the driving altitude. The factors were computed using MOBILE 1, which is a computer program developed by the Environmental Protection Agency to calculate emission factors based on a set of given parameters. The parameters used for the factors given in Appendix 10-A are:

a) An average driving speed of 45 miles per hour.
b) A mean winter temperature of 25°F and a mean summer temperature of 55°F.

c) High altitude driving (5,000 feet above sea level)

d) Hot engine temperature (10% cold start engines)

e) Emissions projected for cars in 1990.

Based on the anticipated distribution of people between Meeker and Rifle, it can be assumed that fourteen percent of the traffic will flow to Meeker from the Rio Blanco Store intersection. The balance will flow to Rifle with 100% of the flow being shown to occur between the Tract and the Rio Blanco Store.

1.2.4 Population Growth

Secondary impacts arise from growths in population that are directly attributable to the construction and operation of a plant. For the C.B. project, the lack of sufficient skilled labor being available locally will necessitate an influx of workers from other areas. Not only will people be required for employment at the plant, but additional employment is generated for people in service sector jobs. Manpower curves (Appendix 9.0) have been projected for the project and the resulting population increases in towns near the plant site are anticipated to be as presented in Table VI-6.

TABLE VI-6
PROJECTED LOCAL POPULATION INCREASES
AS A RESULT OF THE PROJECT

Year	Rifle	Meeker	Silt	Other Areas	Total
1981	885	290	140	105	1,420
1982	1,835	655	300	195	2,985
1983	4,255	1,565	695	435	6,950
1984	6,150	2,250	1,005	630	10,035
1985	9,080	3,420	1,490	895	14,885
1986	10,080	3,785	1,650	1,000	16,515
1987	11,015	4,095	1,800	1,105	18,015
1988	11,165	4,255	1,835	1,080	18,335
1989	10,925	4,340	1,805	990	18,060
1990	11,430	4,680	1,900	980	18,990
1991	10,995	4,530	1,835	915	18,325

As is evident from this table, the population increases are the largest in 1990 and thus the maximum impacts occur in this year. The secondary impacts of this project within the communities will arise from three sources; increased home heating emissions, increased vehicle emissions, and increased railroad traffic at the plant siding in Rifle. The number of housing units required for the increased population has also been projected and is presented in Table VI-7. The primary heating source on the Western

Slope is natural gas. Even though natural gas is a very clean burning source of heat, some emissions can be attributed to home heating. Based on the number of housing units predicted for 1990, a gas usage of 136 thousand standard cubic feet per year per housing unit, a six month heating season, and the emission factors presented in Appendix 10-B, the emissions are calculated to be as presented in Table VI-8.

TABLE VI-7
HOUSING DEMAND RESULTING FROM PROJECT OPERATION
Total Housing Units

Year	Rifle	Meeker	Silt	Other Areas
1981	305	130	50	25
1982	635	265	105	55
1983	1,465	610	245	120
1984	2,115	880	350	175
1985	3,110	1,295	520	260
1986	3,455	1,440	575	280
1987	3,780	1,575	630	315
1988	3,820	1,590	635	320
1989	3,710	1,545	620	310
1990	3,860	1,610	645	320
1991	3,705	1,545	610	310

TABLE VI-8
EMISSIONS FROM HOME HEATING

Town	Carbon Monoxide (lb/hr)	Sulfur Dioxide (lb/day)	Particulates (lb/day)	Nitrogen Oxides (lb/day)	Hydrocarbons (lb/day)
Rifle	2.4	1.7	44	232	24
Meeker	1.0	.72	18	96	9.6
Silt	0.4	.28	7.2	38	3.8
Other Areas	0.2	.14	3.6	19	1.9

The increased population will also bring about an increase in vehicles. The emission from this vehicle source is dependent on the number and type of vehicle and how far they are driven. Based on information received from EPA, the following assumptions are made:

- 1.7 vehicles per household
- 13,500 miles are driven each year per vehicle
- There will be a 93% car - 7% light truck mix

The emissions from this increase in vehicular traffic are presented in Table VI-9, and were calculated using the emission factors from Appendix 10-A.

TABLE VI-9
EMISSIONS FROM VEHICLE TRAFFIC

Town	Carbon Monoxide (lb/hr)	Sulfur Dioxide (lb/day)	Particulates (lb/day)	Nitrogen Oxides (lb/day)	Hydrocarbons (lb/day)
Rifle	205	70	134	1,040	577
Meeker	86	29	56	432	241
Silt	34	12	22	173	96
Other Areas	17	6	11	86	48

The rail sidings near Rifle will be used to bring in limestone and other supplies for plant operation. The increased rail traffic will have a resultant effect on the level of emissions. Ten cars per day for limestone (100 tons per car) and 5 cars per day for other supplies were assumed. This results in the equivalent of about one train per week (assuming 105 cars/train, 5 engines/train) of increased rail traffic due to the project and the use of a switch engine to maneuver the rail cars. The train would spend about an average of two hours per day within the "air quality affected zone", (approximately 40 miles). The switch engine would average two hours per day usage also. Within the assumed criteria and the emissions factors listed in Appendix 10-C, the emission from the increased rail traffic is calculated to be as presented in Table VI-10.

The cumulative effect of these emissions are presented in Tables II-3 and II-4.

TABLE VI-10
EMISSIONS FROM RAILROAD TRAFFIC

Carbon Monoxide (lb/day)	Sulfur Dioxide (lb/day)	Particulates (lb/day)	Nitrogen Dioxides (lb/day)	Hydrocarbons (lb/day)
390	171	75	1,110	282

2.0 Effects of Air Pollutants on Soils, Vegetation and Wildlife

2.1 Categorization of Soils and Vegetation Types in the C-b Vicinity

Soils in the vicinity of the C-b Tract have been intensively sampled, analyzed physically and chemically, and described according to standard soil classification techniques. The characteristics of each of the soil types are discussed in detail in Section 3.2 of Appendix 8-B, and summarized

in Table 3.2-3 of that Appendix. Pertinent features of the soils in the area of maximum expected impact include an average cation exchange capacity (CEC) of 30.5 meq/100 gm and moderate to high organic matter with an average of about 3 percent. In addition, the average pH of the soils in the vicinity is 8.2 with a range from 7.2 to 8.6 with all but two samples 8.0 or greater. The high pH is an expression of the calcareous nature of these soils that have generally high calcium concentrations of 4380 ppm on the average. The average exchangeable sodium percentage is 2.1 with a range from 1.1 to 7.9 percent.

Categorization of vegetation in the vicinity of the C-b Tract has identified 14 plant communities. Detailed descriptions of these plant communities and the major species comprising them are given in Section 3.3 of Appendix 8-B. Table VI-11a here is a listing of all species present on or near the C-b Tract. Species in Table VI-11a that are marked with asterisks are those known to be sensitive to the air pollutants indicated, even though in all cases sensitivity thresholds are much greater than the maximum concentrations expected from C-b emissions, as discussed in Section V.

2.2 Maximum Expected Pollutant Concentrations

Table VI-11b below summmarizes the modeling results, and the isopleths in Section V indicate the spatial locations of these maxima. Conversion from g/m^3 to ppm was done using the same ambient conditions that were used in calculating the concentrations as indicated in Table VI-11b.

Criteria pollutants for which anticipated concentration will exceed de minimus levels are SO_2, TSP, and NO_x. Model calculations (Section V) show that the emission of these pollutants will result in concentrations that comply with both ambient and incremental air quality standards. Compliance with established standards will ensure that environmental impacts are precluded or minimized. The maximum expected ground level concentrations are anticipated to occur primarily within the pinyon-juniper woodland and chained pinyon-juniper rangeland communities.

2.3 Effects on Maximum Concentration of Pollutants on the Types of Soils, Vegetation and Wildlife Found Within the Impact Area

2.3.1 Effects on Soils

The EPA has published sensitivity criteria for soils with respect to acid precipitation (McFee, 1980). The non-sensitive category includes calcareous soils and soils with an average cation exchange capacity (CEC) greater than 15.4 meq/100 gm. The calcareous soils of the C-b vicinity

Table VI-11a ALPHABETICAL LISTING OF COMMON NAMES FOR THE FLORA OF TRACT C-b

Common Name	Scientific Name
TREES, SHRUBS, AND VINES	
Antelope bitterbrush	Purshia tridentata
Big sagebrush	Artemisia tridentata
Blue clematis	Clematis columbiana
* Box elder	Acer negundo
Chokecherry	Prunus virginiana var. melanocarpa
Currant	Ribes cereum
*,** Douglas-fir	Pseudotsuga menziesii
Four-winged saltbush	Atriplex canescens
Gambel's oak	Quercus gambelii
Golden currant	Ribes aureum
Greasewood	Sarcobatus vermiculatus
Horsebrush	Tetradymia canescens
Mormon tea	Ephedra viridis
Mountain mahogany	Cercocarpus montanus
** Narrow-leaf cottonwood	Populus angustifolia
** Oregon grape	Mahonia repens
Pinyon pine	Pinus edulis
Prickly pear	Opuntia polyacantha
Rabbitbrush	Chrysothamnus viscidiflorus
Rock spirea	Holodiseus dumosus
Rocky Mountain juniper	Juniperus scopulorum
Rubber rabbitbrush	Chrysothamnus nauseosus
* Serviceberry	Amelanchier alnifolia
Shadscale	Atriplex confertifolia
Siberian elm	Ulmus pumila
Silver buffaloberry	Shepherdia argentea
Skunkbush	Rhus trilobata

Table VI-11a ALPHABETICAL LISTING OF COMMON NAMES OF THE FLORA OF TRACT C-b (Continued)

Common Name	Scientific Name
Smooth currant	Ribes inerme
Snakeweed	Gutierrezia sarothrae
*Snowberry	Symphoricarpos orephilus
Utah juniper	Juniperus osteosperma
Western virgin's-bower	Clematis ligusticifolia
Wild buckwheat	Eriogonum lonchophyllum
Wild hops	Humulus lupulus var. neomexicanus
** Wild rose	Rosa woodsii
**Willow	Salix sp.
Winter fat	Ceratoides lanata
HERBS	
** Alfalfa	Medicago sativa
Alumroot	Heuchera parvifolia
Aster	Aster sp.
Balsam root	Balsamorhiza sagittata
Baltic rush	Juncus arcticus ssp. ater
Barnyard grass	Echinochloa crus-galli var. mitis
Bastard toadflax	Comandra pallida ssp. umbellata
Beard tongue	Penstemon sp.
Bee plant	Cleome serrulata
Biennial wormwood	Artemisia biennis
Blue-bunch wheatgrass	Agropyron spicatum
Blue grama	Bouteloua gracilis
Blue lettuce	Lactuca tatarica ssp. pulchella
Canada thistle	Cirsium arvense
Cattail	Typha latifolia
Cheatgrass	Bromus tectorum
Checker mallow	Sidalcea neomexicana
Cinquefoil	Potentilla gracilis
Clover	Trifolium gymnocarpon
Colorado bedstraw	Galium coloradoensis

Table VI-11a ALPHABETICAL LISTING OF COMMON NAMES OF THE FLORA OF TRACT C-b (Continued)

Common Name	Scientific Name
Common reed	Phragmites australis
Common sunflower	Helianthus annuus
Crested wheatgrass	Agropyron desertorum
Curly-cup gumweed	Grindelia squarrosa
Dandelion	Taraxacum officinale
* Darnel (Perennial ryegrass)	Lolium perenne
Death camas	Zigadenus venenosus var. gramineus
Dock	Rumex sp.
Double bladderpod	Physaria floribunda
Easter daisy	Townsendia hookeri, Townsendia incana
Eriogonum	Eriogonum flexum
** Evening primrose	Calylophus hartwegii ssp. lavandulifolius Oenothera trichocalyx, Oenothera sp.
Evening star	Mentzelia rusbyi, Mentzelia sp.
Fairy candelabra	Androsace septentrionalis
False dandelion	Agoseris glauca
False flax	Camelina microcarpa
False gromwell	Onosmodium molle var. occidentalis
False Solomon's seal	Smilacina stellata
Fireweed	Epilobium sp.
Foxtail barley	Hordeum jubatum
Glaucous aster	Aster glaucodes
Goat's beard	Tragopogon dubius
Golden aster	Heterotheca villosa
Golden ragwort	Senecio multilobatus
Goldenrod	Solidago sparsiflora
Golden smoke	Corydalis aurea
Goldenweed	Haplopappus nuttallii
** Goosefoot	Chenopodium fremontii, Chenopodium sp.
Great Basin wildrye	Elymus cinereus
Green sage	Artemisia dracunculus ssp. glauca
Gumbo lily	Oenothera caespitosa
Horsetail	Equisetum arvense

Table VI-11a ALPHABETICAL LISTING OF COMMON NAMES OF THE FLORA OF TRACT C-b (Continued)

Common Name	Scientific Name
Horseweed	Conyza canadensis
Indian paintbrush	Castilleja chromosa, Castilleja linariaefolia
**Indian ricegrass	Oryzopsis hymenoides
Japanese brome	Bromus japonicus
Junegrass	Koeleria gracilis
Kentrophyta milk vetch	Astragalus kentrophyta
Kentucky bluegrass	Poa pratensis
Larkspur	Delphinium nelsoni
Little ricegrass	Oryzopsis micrantha
Long-leaved phlox	Phlox longifolia
Lupine	Lupinus argenteus, Lupinus sp.
Malcolmia	Malcolmia africana
Mariposa lily	Calochortus gunnisoni, Calochortus nuttallii
Marsh elder	Iva xanthifolia
Meadow goldenrod	Solidago canadensis
Miner's candle	Cryptantha sp.
Moss phlox	Phlox hoodii
Mountain peppergrass	Lepidium montanum
Much-branched gayophytum	Gayophytum ramosissimum
Mutton grass	Poa fendleriana
Needle-and-thread grass	Stipa comata
Nodding brome	Bromus porteri
Nodding eriogonum	Eriogonum cernuum
Nuttail's sunflower	Helianthus nuttallii
Orchard grass	Dactylis glomerata
Pasque flower	Pulsatilla patens ssp. multifida
Pasture sage	Artemisia frigida
Peppergrass	Lepidium perfoliatum
**Phacelia	Phacelia idahoensis
Pigweed	Amaranthus retroflexus
Prairie bulrush	Scirpus paludosus
Prickly lettuce	Lactuca serriola

Table VI-11a ALPHABETICAL LISTING OF COMMON NAMES OF THE FLORA OF TRACT C-b (Continued)

Common Name	Scientific Name
Puccoon	Lithospermum sp.
Pussytoes	Antennaria rosea, Antennaria parvifolia
Rabbit's-foot grass	Polypogon mouspelliensis
Ragweed	Ambrosia artemisiifolia
Ragwort	Senecio eremophilus var. kingii
Red top	Agrostis gigantea
Rock cress	Arabis holboellii
Russian thistle	Salsola iberica
Sagewort	Artemisia ludoviciana
Sand dropseed	Sporobolus cryptandrus
** Scarlet gilia	Ipomopsis aggretata
Scarlet globe mallow	Sphaeralcea coccinea
Scouring rush	Equisetum hyemale, Equisetum laevigatum
Seaside arrowgrass	Triglochin maritima
Sheep fescue	Festuca brachyphylla
Shore buttercup	Ranunculus cymbalaria
Short-rayed alkali aster	Brachyactis frondosa
Showy milkweed	Asclepias speciosa
Skeletonweed	Lygodesmia grandiflora
Slender wheatgrass	Agropyron trachycaulum
Sloughgrass	Beckmannia syzigachne
Smooth brome	Bromus inermis
Sow thistle	Sonchus arvensis
Speedwell	Veronica salina
Spreading dogbane	Apocynum androsaemifolium
Spurge	Chamaesyce sp., Euphorbia robusta
Squirreltail grass	Sitanion longifolium
Stickseed	Lappula redowskii
Stinging nettle	Urtica dioica
Sugarbowls	Clematis hirsutissima
Sulphur flower	Eriogonum umbellatum
Sweet vetch	Hedysarum boreale
Tansy mustard	Descurainia pinnata

Table VI-11a ALPHABETICAL LISTING OF COMMON NAMES OF THE FLORA OF TRACT C-b (Continued)

Common Name	Scientific Name
Tassel-flower brickellbrush	Brickellia grandiflora
Thistle	Cirsium sp.
Timothy	Phleum pratense
Tule	Scirpus lacustris ssp. validus
Tumble mustard	Sisymbrium altissimum
Twistflower	Streptanthus cordatus
Umbrellawort	Oxybaphus linearis
Utah daisy fleabane	Erigeron utahensis
Watercress	Rorippa nasturtium-aquaticum
Western wheatgrass	Agropyron smithii
White pigweed	Amaranthus albus
White sweet clover	Melilotus alba
Wild flax	Linum lewisii
Wild licorice	Glycyrrhiza lepidota
Winged eriogonum	Eriogonum alatum
Wing-fruited sand verbena	Tripterocalyx micranthus
Yarrow	Achillea lanulosa
Yellow evening primrose	Oenothera strigosa
Yellow sweet clover	Melilotus officinalis
Yucca	Yucca glauca

* Studies have shown this plant to be sensitive to fluorides, but at dosage rates greater than the maximum expected from C-b emissions.

** Same as above with respect to sulfur dioxide.

have an average CEC greater than 30 meq/100 gm and an average calcium concentration greater than 4,000 ppm, placing then clearly in the non-sensitive class. No effects are expected in the maximum expected concentration areas since the soils are non-sensitive. At greater distances, concentrations decrease and therefore no impact will be discernible at greater distances from the tract. In general, acid rain is not considered a problem with semi-arid western soils.

Table VI-11b
Maximum expected off-tract concentrations for pollutants that are expected to exceed de minimus levels

Pollutant	Averaging Time	Concentrations ug/m^3	ppm
SO_2	24 hours	73	0.035*
	Annual	16	0.007**
TSP	24 hours	27	
	Annual	7	
NO_2	Annual	63	0.04**
Particulate F	24 hours	0.87	
	Annual	0.23	
Particulate As	24 hours	0.014	
	Annual	0.004	

* Converted from ug/m^3 at 288°K and 789 mb
** Converted from ug/m^3 at 274°K and 782 mb

2.3.2 Effects on Vegetation and Wildlife

The available literature on environmental effects of air pollutants on native vegetation and wildlife is very limited since most effects research has been done on agronomic crops, livestock, and ornamental plants as noted in the U.S. Fish and Wildlife Service publication entitled Impacts of Coal-Fired Power Plants on Fish, Wildlife, and their Habitats (Dvorak et al. 1978). Review of the National Park Service (NPS) Bibliography of Air Quality Effects on Natural Ecosystems (Howard et al, unpublished) identified documents that are pertinent to the effects of low concentrations or air pollution on the semi arid ecosystems of this region. These included the paper by Hill, et al (1974) and the State of Montana Air Quality Standards Environmental Impact Statement (1979). The EPA Air Quality Criteria for Particulate Matter and Sulfur Oxides in External Review Draft status includes reference to these documents and summarizes the world literature on the effects of sulfur oxides and particulates on natural vegetation. Although these documents

identify certain species as sensitive or very sensitive, the effects of SO_2 and particulates on species of this region are expressed only at concentrations much greater than those shown in Table VI-11b.

Sulfur Dioxide A comprehensive study on the SO_2 susceptibility of many species that are also present on or near the tract was initiated by Hill and others (1974) in response to the lack of available literature on the effects of SO_2 exposure at low concentrations. The investigators subjected the vegetation of many different plant communities to SO_2 concentrations as low as 0.5 ppm. The study determined that nearly all of the 87 species fumigated were unaffected by short term exposures less than 2 ppm (about 5,300 ug/m^3 at 20°C and 1 atm).

The State of Montana prepared an environmental impact statement (Montana, 1979) during a study of the Montana air quality standards. The document summarized the available literature on SO_2 effects as concentrations below 0.5 ppm. There were no studies reported that were not also summarized in the EPA Draft Criteria Document.

Indian ricegrass (*Oryzopsis hymenoides* R&S Ricker) is categorized as very sensitive (Hill *et al* 1974 and Montana 1979), although Ferenbaugh (1978) has shown that deleterious effects occur only at long term concentrations greater than 0.13 ppm (about 350 ug/m^3 at 20°C fand 1 atm). It should be noted that this concentration far exceeds anticipated levels from C-b emissions as shown in Table VI-11b.

A recent study by Thompson *et al* (1980) investigated the effects of SO_2 and/or NO_2 on several species of native desert plants. Low concentrations of SO_2 (0.2 ppm), NO_2 (0.11 ppm),or SO_2 and NO_2 combined (0.1 ppm NO_2 and 0.22 ppm SO_2) produced no significant difference (= 0.05) between growth or dry weight of exposed plants and controls that were subject to clean filtered air. The concentrations used were much greater than the maximum expected concentrations resulting from C-b emissions as shown in Table VI-11b.

Lichens and bryophytes (mosses and liverworts) are shown to be sensitive to air pollution. Studies of the sensitivity of lichens and bryophytes have shown that the foliose and fruticose types are more sensitive to air pollution than crustose lichens. Lichens in the C-b vicinity are crustose types.

Data on the effects of sulfur dioxide on animals are generally derived from laboratory studies and clear-cut threshold levels for

injury or death are not available (Dvorak et al, 1978). Newman (1980) summarized the known effects on wildlife and no studies on the effects of low SO_2 concentrations were reported. Effects of SO_2 on vegetation are not expected, therefore any secondary effect on wildlife through forage consumption will not occur.

Emissions of SO_2 from C-b operations are not expected to produce effects in vegetation, lower plants, or animals in the vicinity of the Tract.

Nitrogen Dioxide The concentrations of NO_2 required to produce acute injury in vegetation are much greater than SO_2 concentrations (Heck and Brandt, 1977). The pertinent study by Hill et al (1974) included fumigations of NO_2 from 0.1 to 5 ppm, along with the SO_2 exposures. No evidence of synergistic effects at these ratios was detected. The research by Thompson et al (1980) determined no significant synergistic effects at low concentrations of SO_2 and NO_2 combined. The maximum expected annual average NO_2 concentration is only 4 percent of the lowest exposure level used in this study. The EPA Air Quality Criteria for Oxides of Nitrogen (External Review Draft 1978) provides threshold curves of the effects of nitrogen dioxide. Concentrations expected from C-b emissions are far less than the threshold data discussed. The criteria document contains no reference to effects of the low concentrations on species present in the C-b vicinity. No research results on the effects of low NO_2 concentrations were reported in the summary document by Newman (1980) concerning the effects on wildlife. No effects on vegetation or wildlife are expected from NO_2 emissions from the C-b operations.

Particulate Matter Research on the effects of particulate matter on vegetation has been done on the emissions from cement kilns, soot, and coal dust (Montana 1979). Studies reported were typically on massive concentrations not experienced in rural areas. The available information on the effects of low concentration of particulate matter on the vegetation of semiarid climates is virtually non-existent. From the results of all previous research, we can conclude that vegetation or animals will not be affected by the low concentrations of particulate matter anticipated from the operation of the C-b facility.

Other Pollutants Table VI-11b show the maximum expected ground level concentrations of arsenic and fluoride, the two remaining pollutants for which de minimus limits are anticipated to be exceeded.

Impact of these elements on vegetation is usually through gaseous absorption by leaves or root uptake from soils. No gaseous emissions of these substances are expected, and particulate forms will be deposited on the soil surface for the most part. The calcareous, high pH soils of the region have large cation exchange capacities and soils with these characteristics can fix large quantities of trace elements and retain them in an unavailable form (Dvorak _et al_, 1978). Heck and Brandt (1977) and the National Academy of Sciences (1971) reported McCune's (1969) technique of deriving injury threshold values for effects from atmospheric fluoride. Values shown in Table II-11b are below the threshold values. The Montana (1979) study reported that the particulate fluoride form is less damaging than the gaseous flouride for which the threshold values were derived

The effects of fluoride on mammals is primarily through ingestion of gaseous fluoride that accumulates in forage. Particulate fluoride is unable to penetrate leaf tissues, therefore the amounts ingested would be negligible, and the particulate fluoride emitted is in a form that is poorly absorbed by animals (Coffin & Stokinger, 1977).

The effects of fluoride on the soils, vegetation, and animals will not be discernible at the low dosages expected from C-b emissions.

Arsenic deposited to the soil surface tends to be retained in the surface layer or leached slowly, when in solution. Lime in soils may aid in maintaining the available arsenic below toxic levels, according to Dvorak and others (1978). Lime content of the soils in the C-b vicinity is generally high (greater than 5 percent) as discussed in Appendix 8B. Translocation to plant foliage is limited by growth effects of arsenic at toxic levels, and arsenic compounds do not accumulate in mammals (Dvorak _et al_, 1978). The effects of arsenic compounds on the soils, vegetation, and wildlife due to the low concentrations expected from C-b emissions will not occur.

2.4 Summary

In summary, pollutants that are subject to _de minimus_ analysis will not produce discernible effects on the vegetation, wildlife, or soils in the vicinity of the C-b Tract in the areas of expected concentration maxima. Concentrations decrease concomitantly with distance from the Tract, therefore, no discernible effects are expected at distances beyond the areas of concentration maxima.

3.0 Visibility Impact Analysis

3.1 Identification of Worst Case Conditions

The only Class I area in the region with the potential for impact is the Flat Tops Wilderness Area administered by the U.S. Forest Service. Integral vistas from the Flat Tops have not been identified by either the U.S. Forest Service or the State of Colorado. The closest point on the Wilderness area boundary is 56 km from the C-b facility, on an azimuth 84° from north. Limits of the boundary are from azimuths 66° to 97° from north, and therefore winds from only two sectors, W and WSW, have the potential to impact the wilderness area. We have not incorporated the effects of complex terrain on plume dispersion for the visibility analysis, to incorporate conservative estimates of impacts worse than expected in reality.

Worst case meteorological conditions are shown in Table VI-12, and are the W and WSW cases identified as worst cases in Section V of this application. Note that cases one, two, three, five and six do not have the persistence required to allow transport as far as 56 km, the distance to Flat Tops. These frequencies in percent are from the two year baseline meteorological data as indicated. The cumulative frequency of all W and WSW worst dispersion cases is only 0.031%. Only about 0.22 days would have worse conditions. The suggested one day per year frequency would require using unstable cases (Category C) that would have sufficient dispersion to preclude visibility impacts. Case nine was chosen for analysis.

Worst case conditions for general haze did not require analysis, since the level of analysis gave a value for $|C_3|$ less than 0.1, as follows:

$$\tau_{aerosol} = (1.06 \times 10^{-5})(r_{v_o})(Q_{part} + 1.31 Q_{SO_2}) \qquad \text{(p-4)}^*$$

$$= (1.06 \times 10^{-5})(170)[(170) + (1.31)(20.4)]$$

$$= 0.062$$

and

$$C_3 = 0.368\ [1 - \exp(-\tau_{aerosol})] \qquad \text{(p-7)}$$

$$= 0.368\ [1 - \exp(-0.062)]$$

$$= 0.022$$

$|C_3| = 0.022$, less than the 0.1 threshold.

*Equation numbers are from Latimer & Ireson (1980) DRAFT WORKBOOK FOR ESTIMATING VISIBILITY IMPAIRMENT.

TABLE VI-12

Worst Case Meteorology for Visibility Analysis
November 1974 - October 1976 Baseline

Case No.	Stability Category	Wind		Transport		Dispersion Parameter $\sigma_z u$	Percent	
		Dir.	Spd(m/sec)	Time	Distance		Frequency	Cum Freq
1	F	W	1.0	2	7*	80	-	0.0
2	F	W	1.1	2	8*	88	-	0.0
3	E	W	1.5	4	22*	225	-	0.0
4	E	W	2.1	10	76	315	0.014	0.014
5	E	W	2.7	5	49*	405	-	
6	D	W	4.5	3	49*	1575	-	
7	D	WSW	6.8	3	73	2380	0.004	0.018
8	D	WSW	8.0	5	144	2800	0.007	0.025
9	D	W	8.2	4	118	2870	0.006	0.031

*Less than 56 km, the distance to Flat Tops Wilderness Area.

where:

$\tau_{aerosol}$ = optical thickness of a plume, the line of sight integral of the extinction coefficient for aerosol,

r_{v_o} = background visual range,

Q_{part} = particulate emission rate, and

Q_{SO_2} = sulfur dioxide emission rate.

Background ozone concentrations were obtained from Figure 20 of the workbook for January, which was the month in which case nine occurred. We used the maximum of 40 ppb.

The background visual range of 170 km was obtained from Figure 13 of the workbook. The extinction coefficient, b_{ext}, at 0.55 micrometers calculated from this visual range is:

$$b_{ext} = \frac{3.912}{170} = 0.023 \qquad \text{(p-25)}$$

Since no specific targets have been identified, horizontal lines of sight are not known and a range of scattering angles was used as recommended.

The NO_x concentration expected was calculated, assuming neutral stability indicated by the worst case used, as follows:

$$[NO_x] = \frac{6.17 Q_{NO_x}}{\sigma_z u \ x} = \frac{(6.17)(8.2)}{(350)(812)(56)} = 0.003 \qquad \text{(p-18)}$$

$$h = 0.1[NO_x] + [O_3]$$

$$= 0.1(0.003) + 0.04 = 0.040$$

and

$$NO_2 \begin{cases} h, \text{ if } [NO_x] \geq h \\ [NO_x] \text{ otherwise} \end{cases} \qquad \text{(p-19)}$$

$[NO_2] = 0.003$, $h = 0.040$; therefore $[NO_2] = 0.003$.

where:

$[NO_x]$ = NO_x concentration

QNO_x = oxides of nitrogen emission rate

σ_z = vertical standard deviation of plume concentration

u = wind speed

x = downwind distance

$[O_3]$ = ozone concentration

$[NO_2]$ = nitrogen dioxide concentration

3.2 Calculating Worst Case Visual Impacts

The plume flux of the scattering coefficient is given by:

$$Q_{scat\ part} = \frac{1160\ Q_{part}\ (bscat/V)}{\rho} \qquad \text{(p-12)}$$

$$Q_{scat\ part} = \frac{(1160)(7.62)(0.004)}{2.5} = 14.14$$

where:

$Q_{scat\ part}$ = plume flux of the scattering coefficient

bscat/V = scattering coefficient per aerosol volume, the light scattering efficiency per unit aerosol volume concentration, and

ρ = particle density.

The value for bscat/V was obtained from Figure 24 of the Workbook, assuming a standard deviation of particle diameter (ρ_g) of 2 micrometers, and a particle density of 2.5 gn cm^{-3}.

We anticipate NO_x mass emission rates to be greater than five times the particulate emissions rate, therefore we used reference tables for NO_2 impacts as recommended.

$$\tau_{part} = \frac{Q_{scat\ part}}{(2\pi)^{\frac{1}{2}}\ \sigma_z u}$$

$$= \frac{14.14}{(2\pi)^{\frac{1}{2}}(350)(0.2)} = 0.002$$

where:

τ_{part} = optical thickness, the line of sight integral of the extinction coefficient due to particulate matter.

Approximate visual range is given by:

$$r_v = r_{v_0}\ (1 - \tau_{part}/3.912) \qquad \text{(p-35)}$$

$$= 170(1 - 0.002/3.912)$$

$$= 169.9 \simeq 170$$

where:

r_v = visual range, and

r_{v_0} = background visual range.

Calculating the integral plume NO_2 for angles of 22, 30, 45, 60, 90, 135 and 150 degrees, from:

$$\int_{plume} [NO_2]dr = \frac{(7.49 \times 10^5)(56)(0.003)}{\sin \alpha} \qquad \text{(p-36)}$$

α	22	30	45	60	90	135	150
$\int_{plume}$	3.4E5	2.5E5	1.8E5	1.5E5	1.3E5	1.8E5	2.5E5
r_p	30	22	16	13	11	16	22

where:

α = angle between line of sight and plume centerline, and

r_p = plume - observer distance given by:

$r_p = (0.199)(x)/\sin \alpha$; x is the downwind distance.

For $\alpha = 30^o$, $r_p = 22$, we use the table in the Workbook Appendix for 150 km (more conservative than 170) and $r_p = 20$. We used linear interpolation to get the appropriate integral of plume NO_2 for the blue-red ratio, contrast, and ΔE. Similarly, for other values of α, Table VI-13 was constructed.

Workbook recommendations are that if the blue-red ratio is less than 0.90, if plume contrast is less than -0.10, or if ΔE is greater than 4.0, impact on visibility may occur. Table VI-13 shows that all blue-red ratios are greater than 0.90, all contrast values are greater than -0.10, and all values of ΔE are less than 4.0. The probability of adverse or significant impacts may therefore be ruled out, even under the conservative assumptions used.

TABLE VI-13

Values of Blue/Red Ratio, Plume Contrast, and Color Difference Parameter (DELTA E) for Different Line of Sight/Plume Angles α

α	22	30	45	60	90	135	150
B/R Ratio	0.953	0.956	0.919	0.945	0.937	0.919	0.956
Contrast	-0.024	-0.024	-0.020	-0.017	-0.017	-0.020	-0.024
Delta E	2.311	2.926	2.767	2.316	2.535	2.767	2.926

VII REFERENCES

VII.

REFERENCES

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2.0 Definitions

2.1 Abbreviations

ADIP	Diisopropylamine
AGR	Above Ground Retorting
AOSS	Area Oil Shale Supervisor
AQCC	Air Quality Control Commission
BACT	Best Available Control Technology
BSRP	Bevin Sulfur Recovery Plan
BTU	British Thermal Unit
C-a	Federal Prototype Oil Shale Lease Tract C-a
C.B.	Cathedral Bluffs Shale Oil Company
C-b	Federal Prototype Oil Shale Lease Tract C-b
CEC	Cation Exchange Capacity
DDP	Detailed Development Plan
DEA	Diethanolamine
DOI	Department of Interior
EPA	Environmental Protection Agency
ESP	Electrostatic Precipitator
FGD	Flue Gas Desulfurization
GEP	Good Engineering Practice
HP	Horse Power
MDEA	Methyl diethanolamine
NAAQS	National Ambient Air Quality Standard
NPS	National Park Service

NSPS	New Source Performance Standard
OOSI	Occidental Oil Shale, Incorporated
OXY	Occidental Corporate Trademark
PSD	Prevention of Significant Deterioration
SPF	Surface Process Facility
TDS	Total Dissolved Solids
TOSCO	The Oil Shale Company
TSP	Total Suspended Particulate
UOP	Universal Oil Products
VOC	Volatile Organic Compound

2.2 Units

ACFD (acfd)	Actual Cubic Feet per Day
B/L	Battery Limits
BBL (bbl)	Barrel (oil barrel @ 42 gal)
BPCD (B/CD)	Barrels-per-calendar day
BPD (bpd) (B/D)	Barrels-per-day
BPSD (B/SD)	Barrels-Per-Stream Day
CFM (cfm)	Cubic Feet Per Minute
°C	Degree Celsius
ft	Foot
°F	Degree Fahrenheit
GPD (gpd)	Gallons-Per-Day
GPM (gpm)	Gallons-Per-Minute
gpt	Gallons-Per-Ton
gr	Grain
hr	Hour
km	Kilometer
KV	Kilo-volt
KW	Kilowatt
KWA	Kilo Watt Hour
lb	Pound
m	Meter
M	Thousand or Mole (where appropriate)
meq	Milli Equivalent
mg	Milligram

MVA	Mega-Volt-Ampere
ppb	Part-Per-Billion
PPH	Pounds-Per-Hour
ppm (PPM)	Part-Per-Million
ppmv	Part-Per-Million Volume
psi	Pound-Per-Square Inch
psia	Pound-Per-Square Inch Absolute
psig	Pound-Per-Square Inch Guage
SCF	Standard Cubic Feet
SCFD (scfd)	Standard Cubic Feet Per Day (1 atm, 60°F)
T/D (TPD)	Ton-Per-Day
T/Y (TPY)	Ton-Per-Year
ug	Microgram
vol	Volume
wt	Weight

VIII APPENDICIES

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1.0

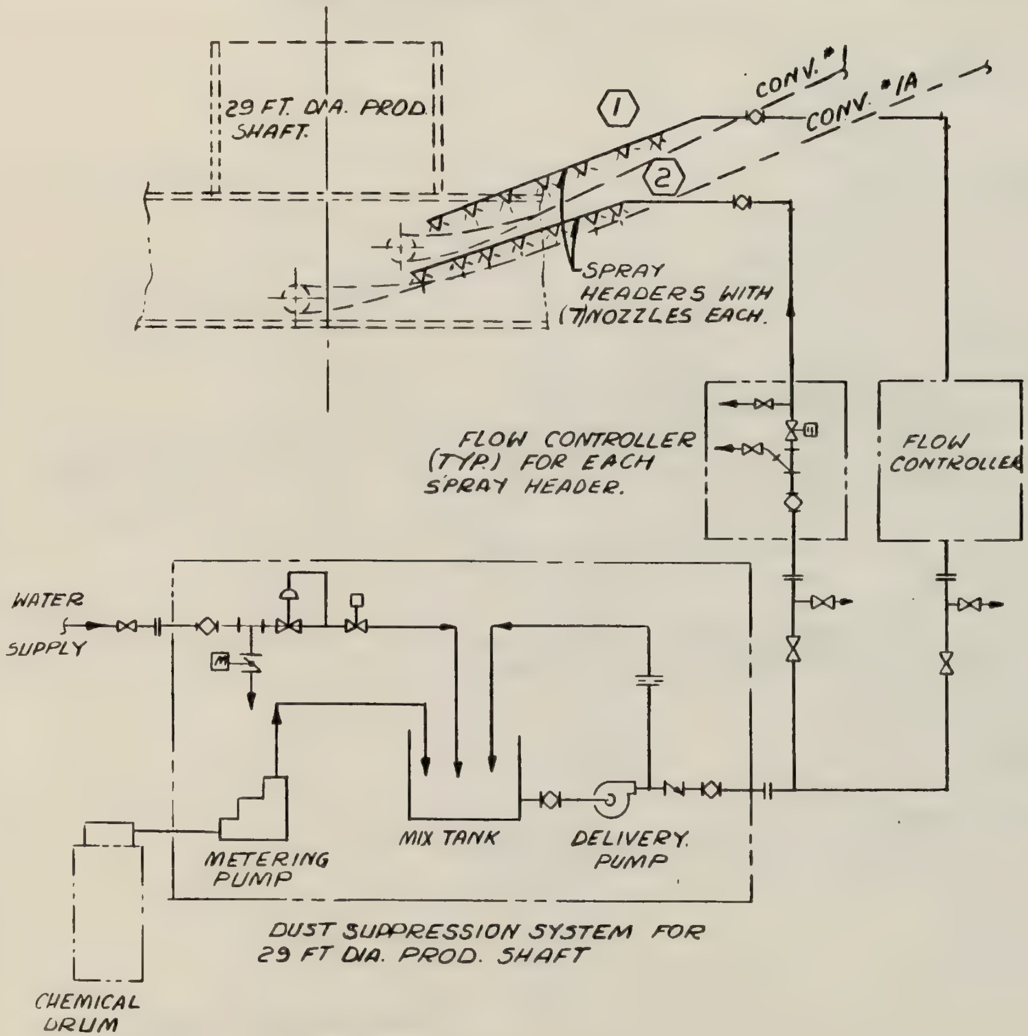
APPENDIX 1.0

Control Equipment Sketches and Schematics

APPENDIX 1.0

CONTROL EQUIPMENT SKETCHES AND SCHEMATICS

TABLE OF CONTENTS



NOTE:-

1. ALL DUST SUPPRESSION EQUIPMENT BY JOHNSON MARCH CORP.
2. .9 TO 1.25 GALLONS PER TON OF CHEMICAL SUPPRESSANT WILL BE USED ON THE RAW SHALE.

NO.	BY	DESCRIPTION	J.E.	S.E.
		REVISIONS		

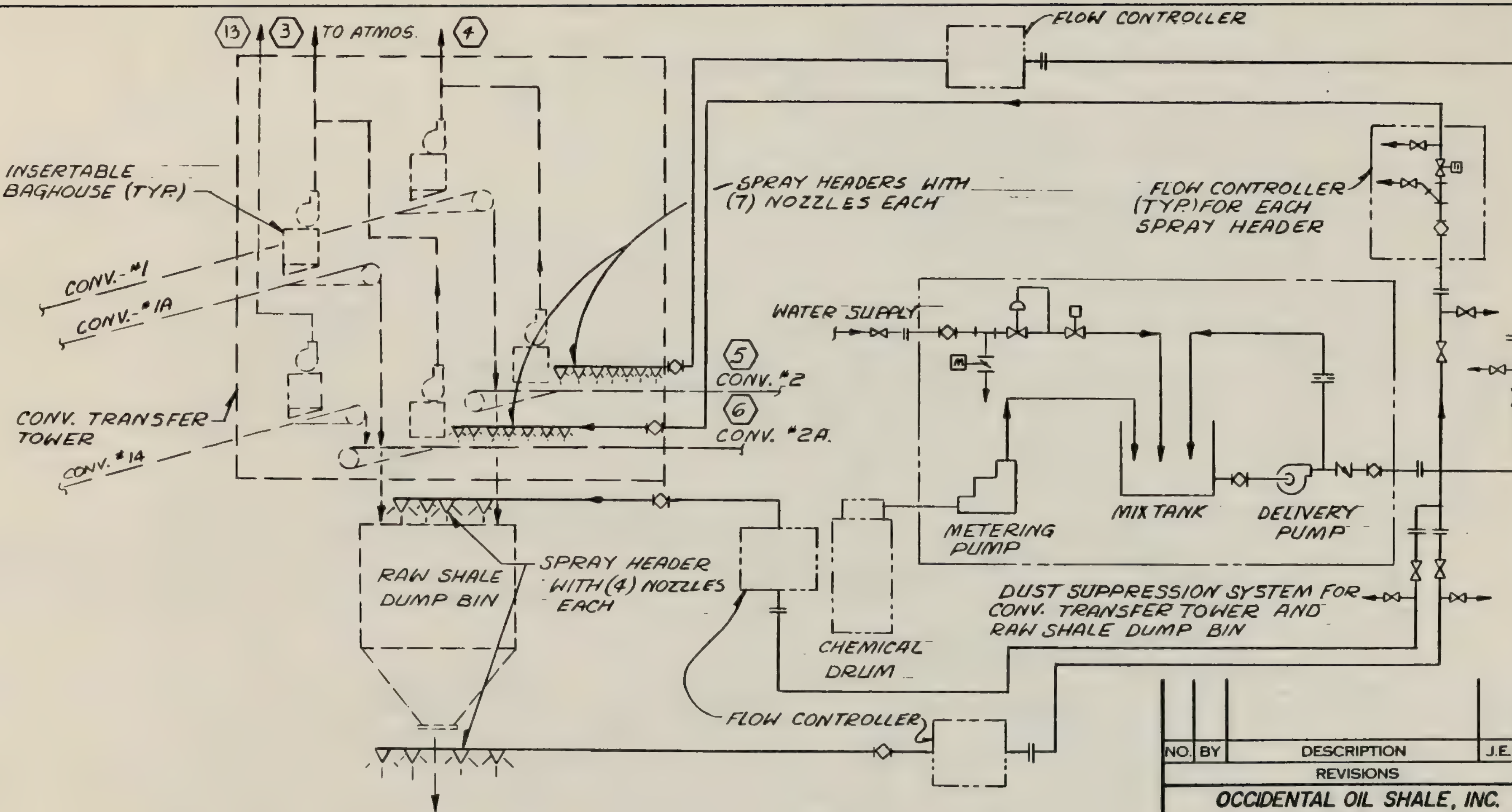
OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO

CHEMICAL DUST SUPPRESSION SYS. CONVEYOR NO'S 1 & 1A

SCALE NONE DR AR 6-2-80 CH [illegible]
SECT. MECH J.E. ____ S.E. ____
AREA ____ APPD ____

Dravo DENVER OPERATIONS
CONTRACT NO. M-7541
DWG NO MSK-1

ISSUE NO. 1 DATE PRINTED 9/25/80



NOTE :-

1. ALL DUST SUPPRESSION EQUIPMENT BY JOHNSON MARCH CORP.
2. SEE PERFORMANCE DATA SHEETS (APPENDIX 2.0)
3. .9 TO 1.25 GALLONS PER TON OF CHEMICAL SUPPRESSANT WILL BE USED ON THE RAW SHALE.

ISSUE NO. 1 DATE PRINTED 9/25/80

NO.	BY	DESCRIPTION	J.E.	S.E.
		REVISIONS		

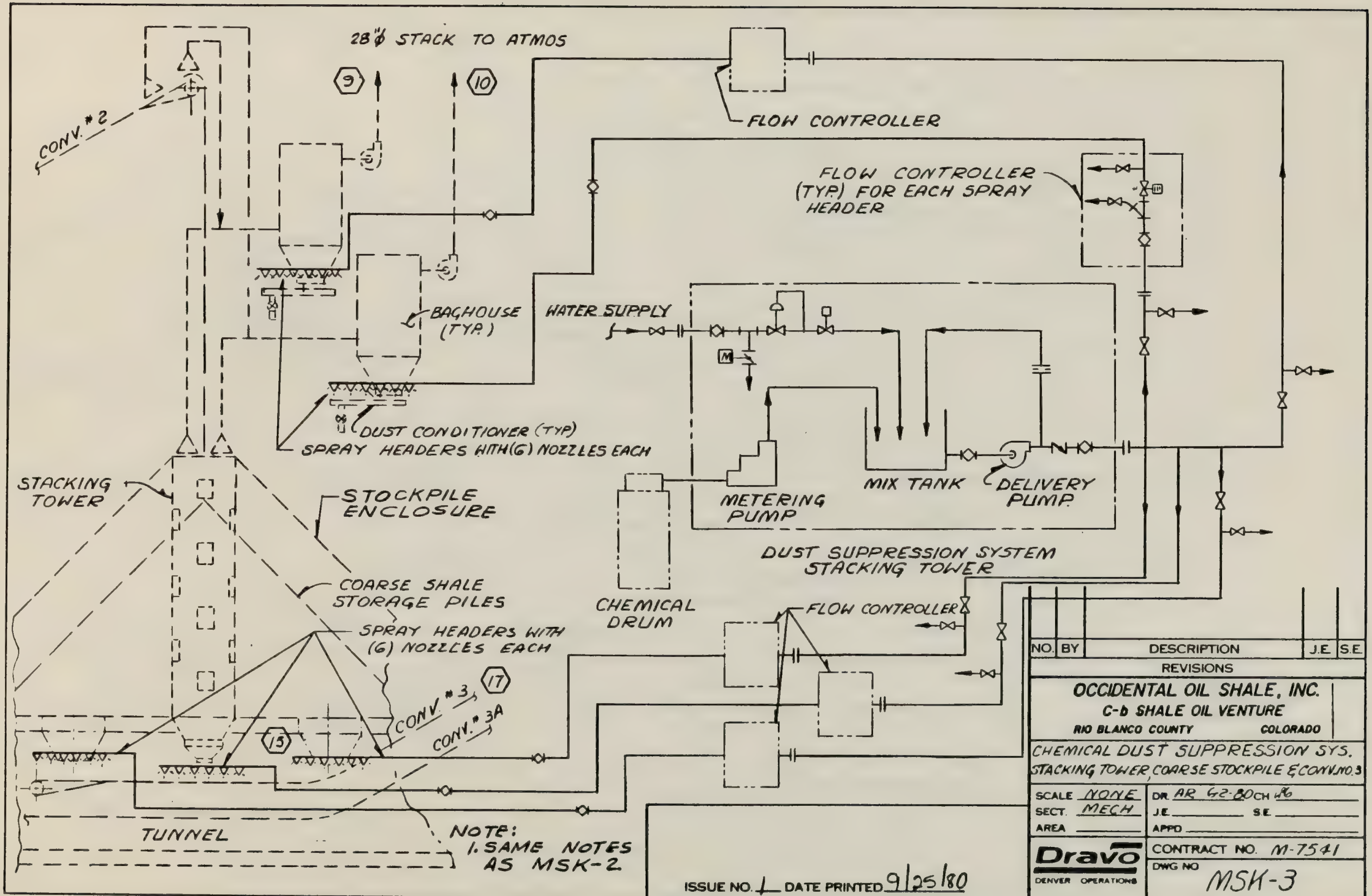
OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO

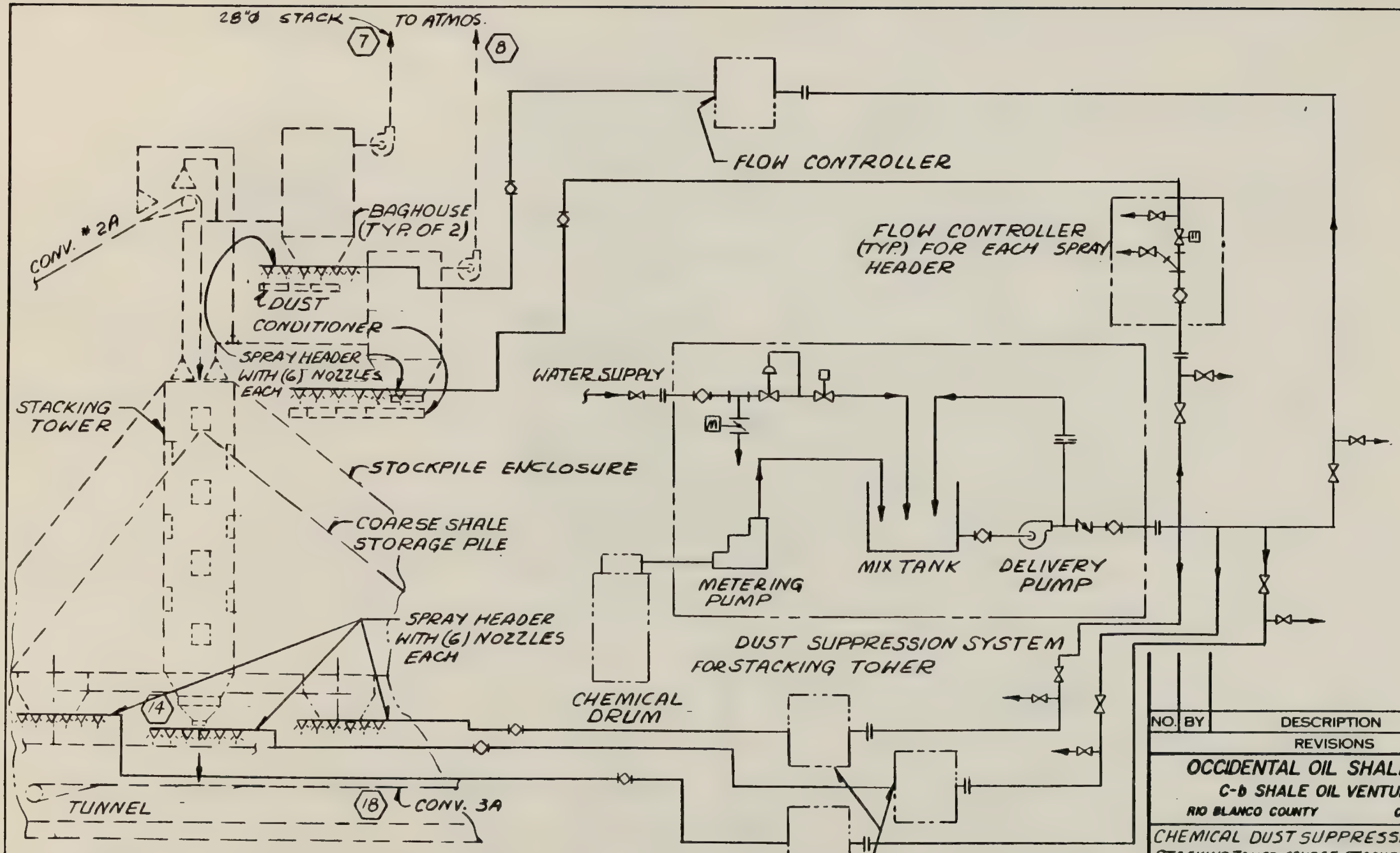
CHEMICAL DUST SUPPRESSION SYS.
CONVEYOR NO'S 2&2A, & RAW SHALE DUMP BIN

SCALE NONE — DR. A.K. 6-2-80 CH. ✓
SECT. MECH — J.E. ____ S.E. ____
AREA ____ — APPD ____

Dravo DENVER OPERATIONS — CONTRACT NO. M-7541

DWG. NO. MSK-2


28"ϕ STACK TO ATMOS
9
10
FLOW CONTROLLER
CONV. #2
FLOW CONTROLLER (TYP.) FOR EACH SPRAY HEADER
BAGHOUSE (TYP.)
WATER SUPPLY
M
DUST CONDITIONER (TYP)
SPRAY HEADERS WITH (6) NOZZLES EACH
STACKING TOWER
STOCKPILE ENCLOSURE
METERING PUMP
MIX TANK
DELIVERY PUMP
DUST SUPPRESSION SYSTEM STACKING TOWER
COARSE SHALE STORAGE PILES
CHEMICAL DRUM
FLOW CONTROLLER
SPRAY HEADERS WITH (6) NOZZLES EACH
17
CONV. #3
CONV. #3A
15
TUNNEL
NOTE:
1. SAME NOTES AS MSK-2
ISSUE NO. 1 DATE PRINTED 9/25/80
NO. BY DESCRIPTION J.E. S.E.
REVISIONS
OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO
CHEMICAL DUST SUPPRESSION SYS.
STACKING TOWER, COARSE STOCKPILE & CONV. NO. 3
SCALE NONE
SECT. MECH
AREA
DR. AR 6-2-80
J.E.
S.E.
APPD
Dravo
DENVER OPERATIONS
CONTRACT NO. M-7541
DWG NO MSK-3



NOTE:-
1. SAME NOTES AS MSK-2

NO.	BY	DESCRIPTION	J.E.	S.E.
		REVISIONS		

OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO

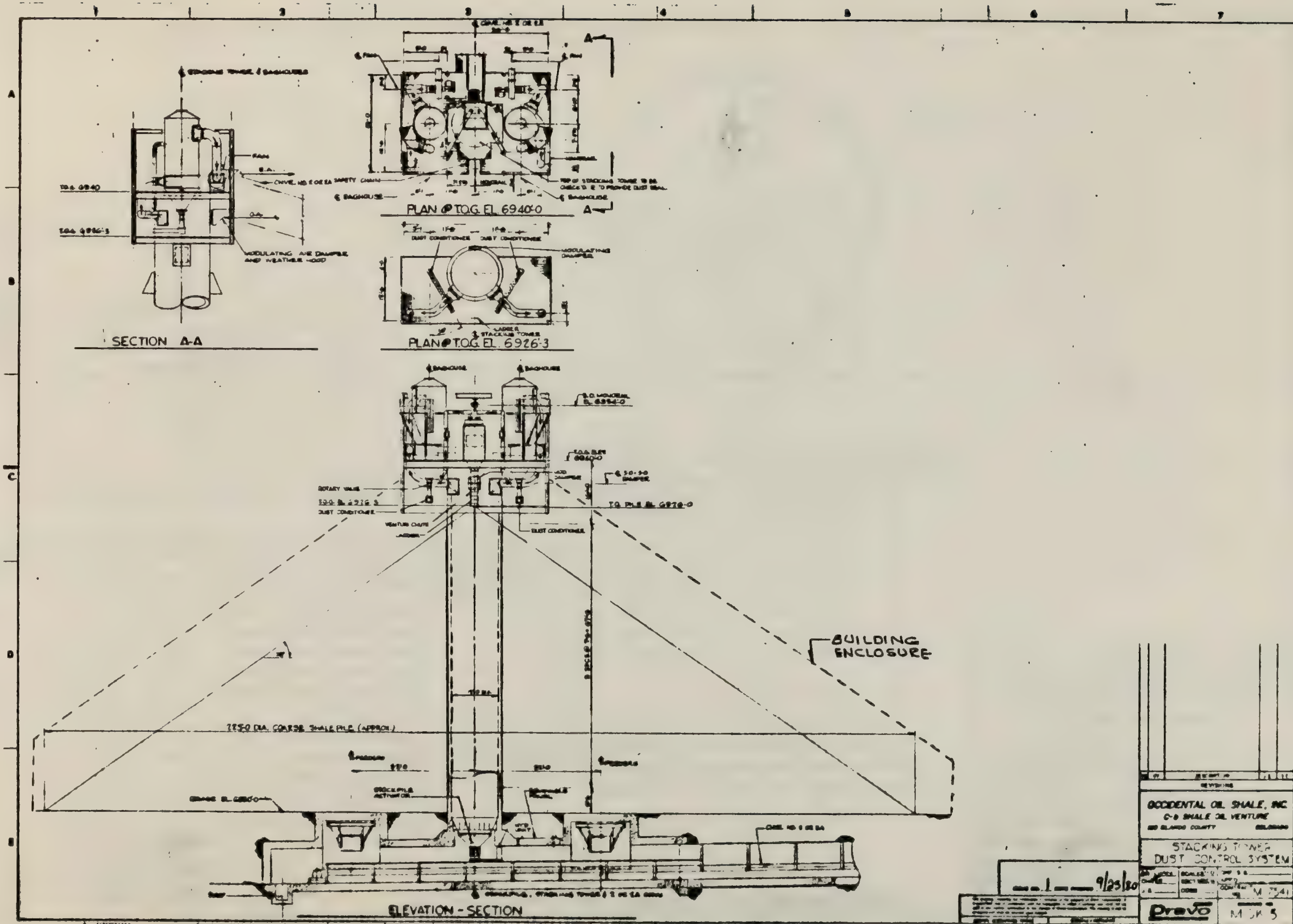
CHEMICAL DUST SUPPRESSION SYSTEM, STACKING TOWER, COURSE STOCKPILE, & CONV. NO. 3A

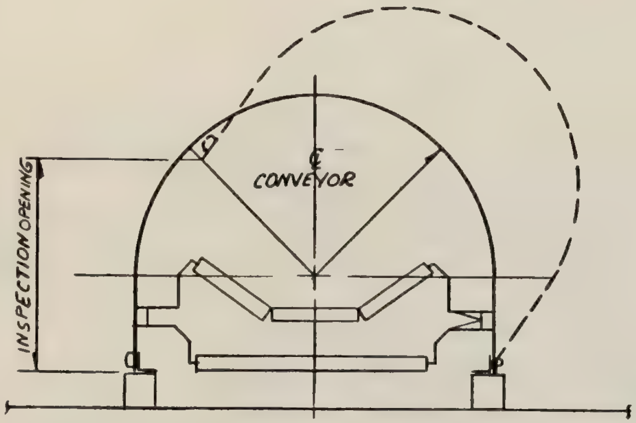
SCALE NONE
SECT. MECH
AREA
DR A.R. 6-2-80 CH
J.E. S.E.
APPD

Dravo DENVER OPERATIONS

CONTRACT NO. M-7541
DWG NO. MSK-4

ISSUE NO. 1 DATE PRINTED 9/25/80

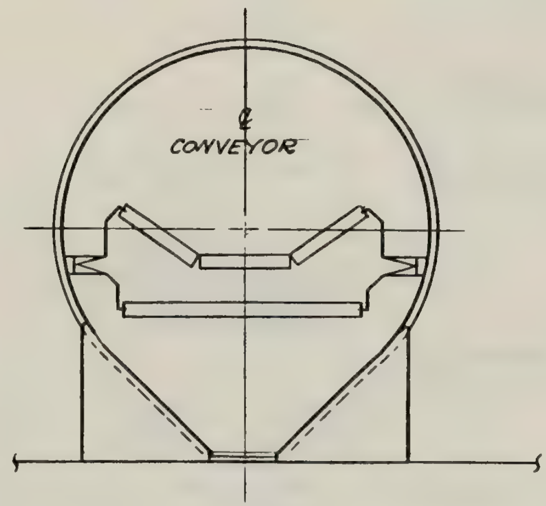

SECTION A-A
PLAN @ T.O.G. EL. 6940'-0
PLAN @ T.O.G. EL. 6926'-3
MODULATING AIR DAMPER AND WEATHER HOOD
MODULATING DAMPER
ROTARY VALVE
DUST CONDITIONER
VENTURI CHUTE
T.O. PILE EL. 6970'-0
BUILDING ENCLOSURE
STOCKPILE ACTIVATOR
ELEVATION - SECTION
OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO
STACKING TOWER
DUST CONTROL SYSTEM
9/25/80
Dravo
M SK 5



PARTIALLY COVERED CONVEYOR

EMISSION PT. ⬡	EMISSION SOURCE	EFF. %	POLLUTANT	PROPOSED CONTROL SYS.
1	42" CONV. #1	98.5	RAW SHALE DUST	CHEM. SPRAY & CONV. COVER
2	42" CONV #1A	98.5	RAW SHALE DUST	
5	42" CONV. #2	98.5	RAW SHALE DUST	
6	42" CONV. #2A	98.5	RAW SHALE DUST	
17	36" CONV. #3	98.5	RAW SHALE DUST	
18	36" CONV. #3A	98.5	RAW SHALE DUST	
20	36" CONV. #4	95	RAW SHALE DUST	
21	30" CONV. #4A	95	RAW SHALE DUST	
22	42" CONV. #6	95	RAW SHALE DUST	CHEM SPRAY & CONV. COVER
12	24" CONV. # 14	90	RAW SHALE DUST	CONV. COVER
16	42" CONV. # 15	90	SPENT SHALE DUST	
37	42" CONV. # 16	90	SPENT SHALE DUST	

THESE CONVEYORS SIMILAR TO CONVEYOR COVERS INC. LOX-COVER



TOTALLY COVERED CONVEYOR

CONVEYOR SIZE AND NUMBER	CAPACITY TONS/DAY
30" CONV. #7	30,865
30" CONV. #7A	30,865
30" CONV. #8	30,865
30" CONV. #8A	30,865
42" CONV. #9	46,850
18" CONV. #10	1,016
42" CONV. #11	52,700

THESE CONVEYORS SIMILAR TO CAMBELT INTERNATIONAL CORP. CAMSPAN TOTALLY ENCLOSED

ISSUE NO. 1 DATE PRINTED 9/25/80

NO.	BY	DESCRIPTION	J.E.	S.E.

REVISIONS

OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO

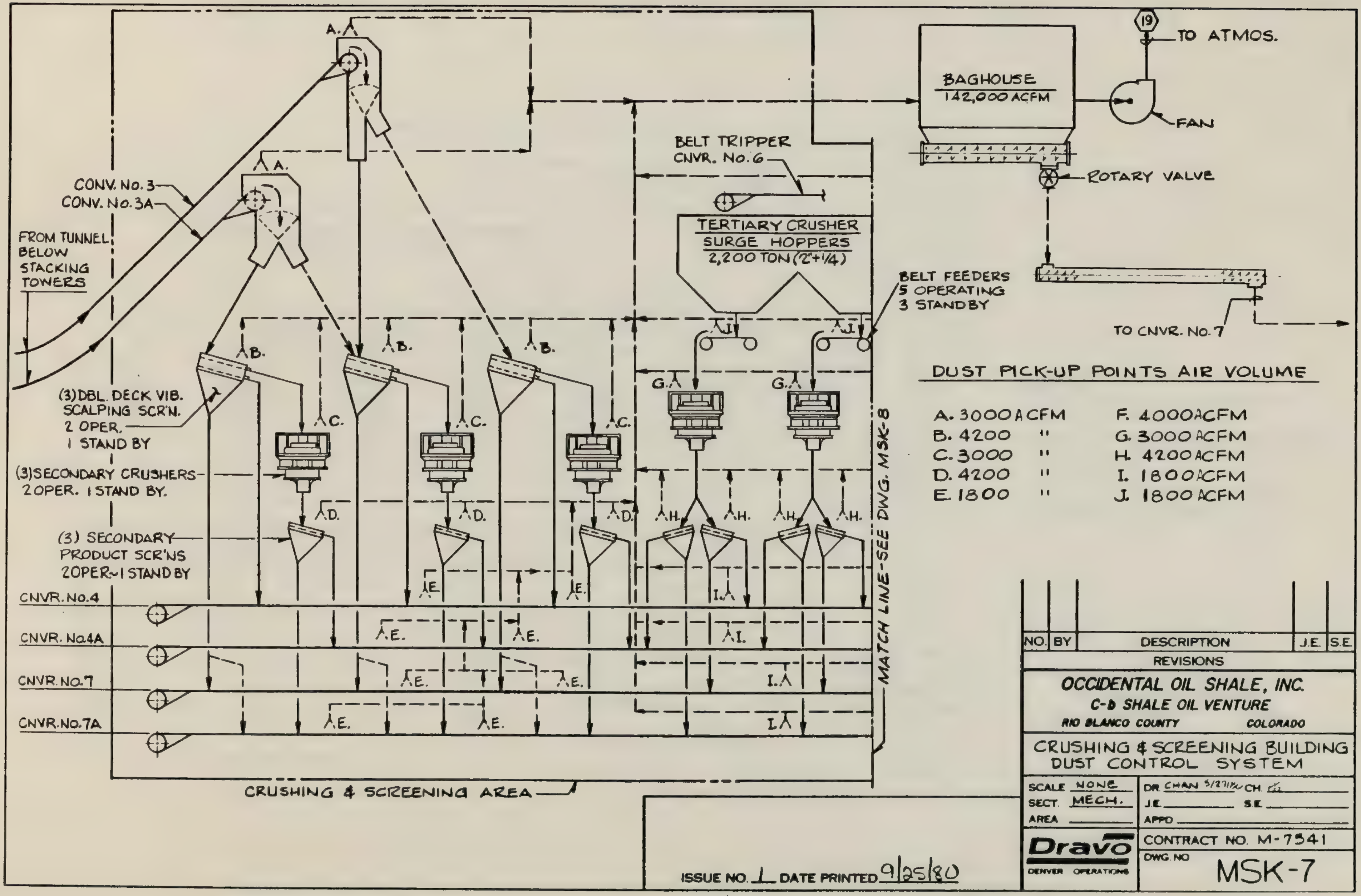
CONVEYOR DETAILS

SCALE NONE
SECT. MECH
AREA

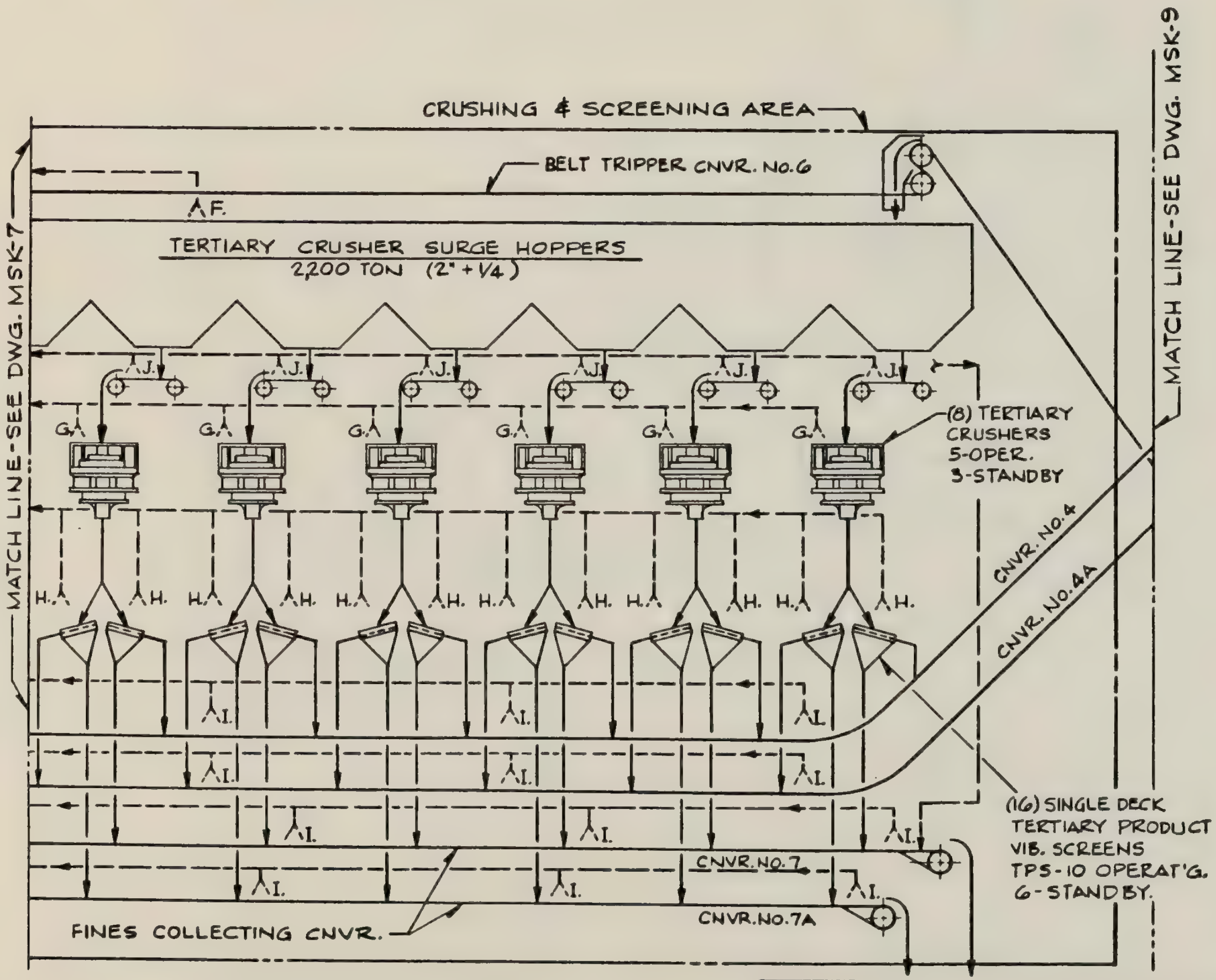
DR. AR 6-6-80 CH. WL
J.E. S.E.
APPD

Dravo DENVER OPERATIONS

CONTRACT NO. M-7541
DWG. NO. MSK-6



TO ATMOS.
19
BAGHOUSE
142,000 ACFM
FAN
ROTARY VALVE
BELT TRIPPER
CNVR. No. 6
TERTIARY CRUSHER
SURGE HOPPERS
2,200 TON (2"+1/4)
BELT FEEDERS
5 OPERATING
3 STANDBY
TO CNVR. No. 7
CONV. No. 3
CONV. No. 3A
FROM TUNNEL BELOW STACKING TOWERS
(3) DBL. DECK VIB. SCALPING SCR'N. 2 OPER. 1 STAND BY
(3) SECONDARY CRUSHERS 2 OPER. 1 STAND BY.
(3) SECONDARY PRODUCT SCR'NS 2 OPER~1 STAND BY
CNVR. No. 4
CNVR. No. 4A
CNVR. No. 7
CNVR. No. 7A
A.
B.
C.
D.
E.
G.
H.
I.
J.
MATCH LINE-SEE DWG. MSK-8
CRUSHING & SCREENING AREA
DUST PICK-UP POINTS AIR VOLUME
A. 3000 ACFM
B. 4200 "
C. 3000 "
D. 4200 "
E. 1800 "
F. 4000 ACFM
G. 3000 ACFM
H. 4200 ACFM
I. 1800 ACFM
J. 1800 ACFM
NO. BY DESCRIPTION J.E. S.E.
REVISIONS
OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO
CRUSHING & SCREENING BUILDING
DUST CONTROL SYSTEM
SCALE NONE
SECT. MECH.
AREA
DR. CHAN 5/27/80 CH.
J.E. S.E.
APPD
Dravo
DENVER OPERATIONS
CONTRACT NO. M-7541
DWG. NO
MSK-7
ISSUE NO. 1 DATE PRINTED 9/25/80



NOTES:

1. FOR DUST PICK-UP POINTS AIR VOLUME SEE DWG.
2. MANUAL VALVES WILL BE USED TO CLOSE THE PICK-UP POINTS NOT IN OPERATION.
3. SEE PERFORMANCE DATA SHEETS APPENDIX 2.0.

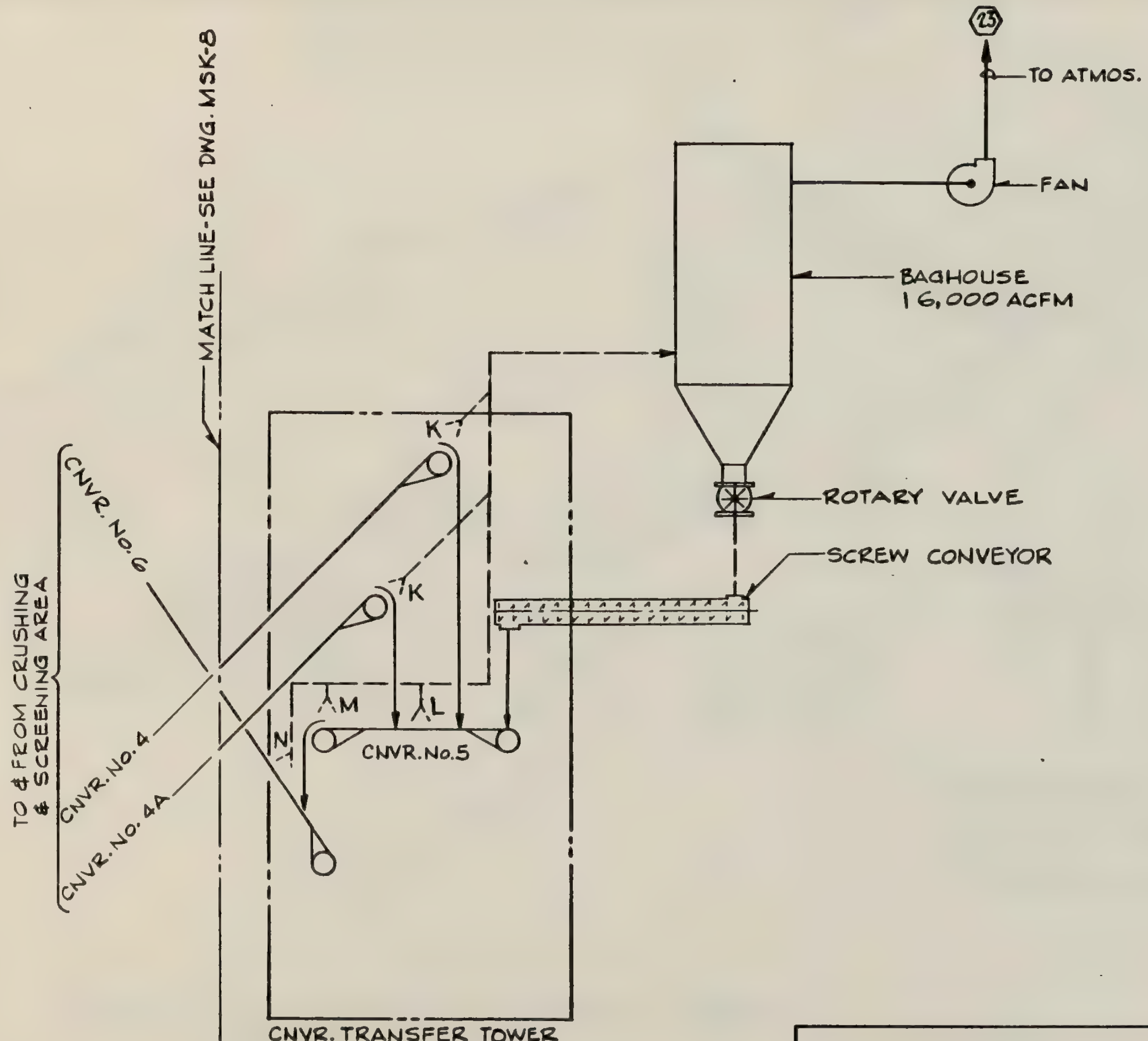
NO.	BY	DESCRIPTION	J.E.	S.E.
		REVISIONS		

OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO

CRUSHING & SCREENING BUILDING DUST CONTROL SYSTEM

SCALE NONE	DR. CHAN 9/18/80 CH. 46
SECT. MECH.	J.E. S.E.
AREA	APPD.
Dravo DENVER OPERATIONS	CONTRACT NO. M-7541
	DWG NO MSK-8

ISSUE NO. 1 DATE PRINTED 9/25/80



DUST PICK-UP POINTS AIR VOLUME

K = 2600 ACFM
L = 3800 "
M = 3200 "
N = 3800 "

NO.	BY	DESCRIPTION	J.E.	S.E.
		REVISIONS		

OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY / COLORADO

CONVEYOR TRANSFER TOWER
DUST CONTROL SYSTEM

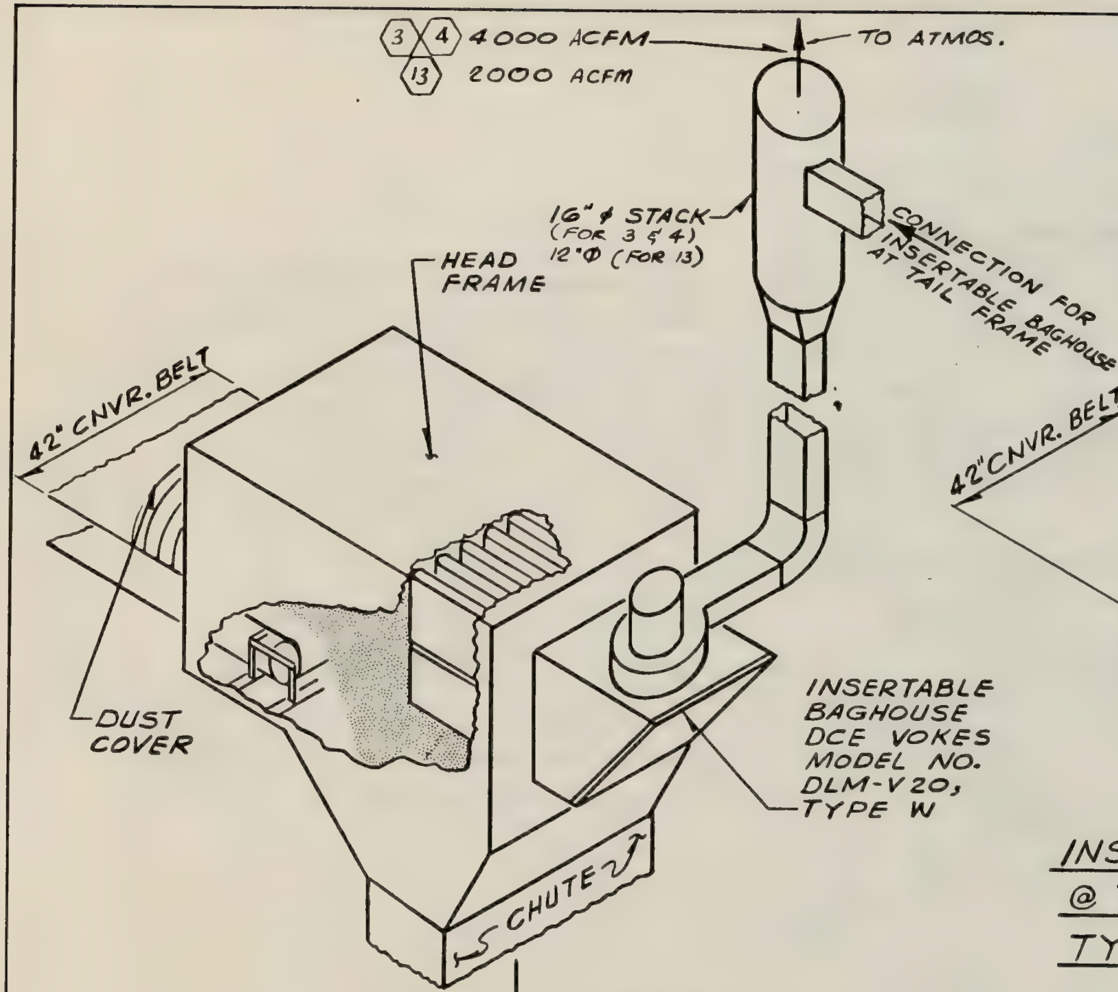
SCALE NONE
SECT. MECH.
AREA

DR CHAN 7/29/80 CH. C
J.E. S.E.
APPD

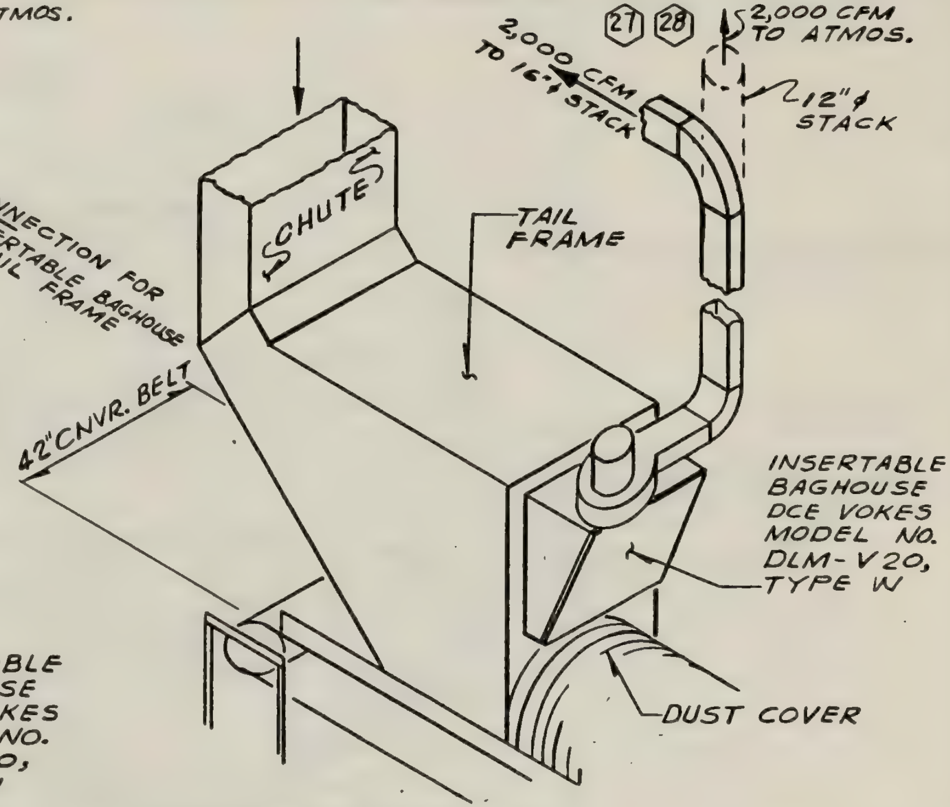
Dravo DENVER OPERATIONS

CONTRACT NO. M-7541
DWG. NO. MSK-9

ISSUE NO. 1 DATE PRINTED 9/25/80



INSERTABLE BAGHOUSE @HEAD FRAME
TYPICAL INSTL.



INSERTABLE BAGHOUSE
@ TAIL FRAME
TYPICAL INSTL.

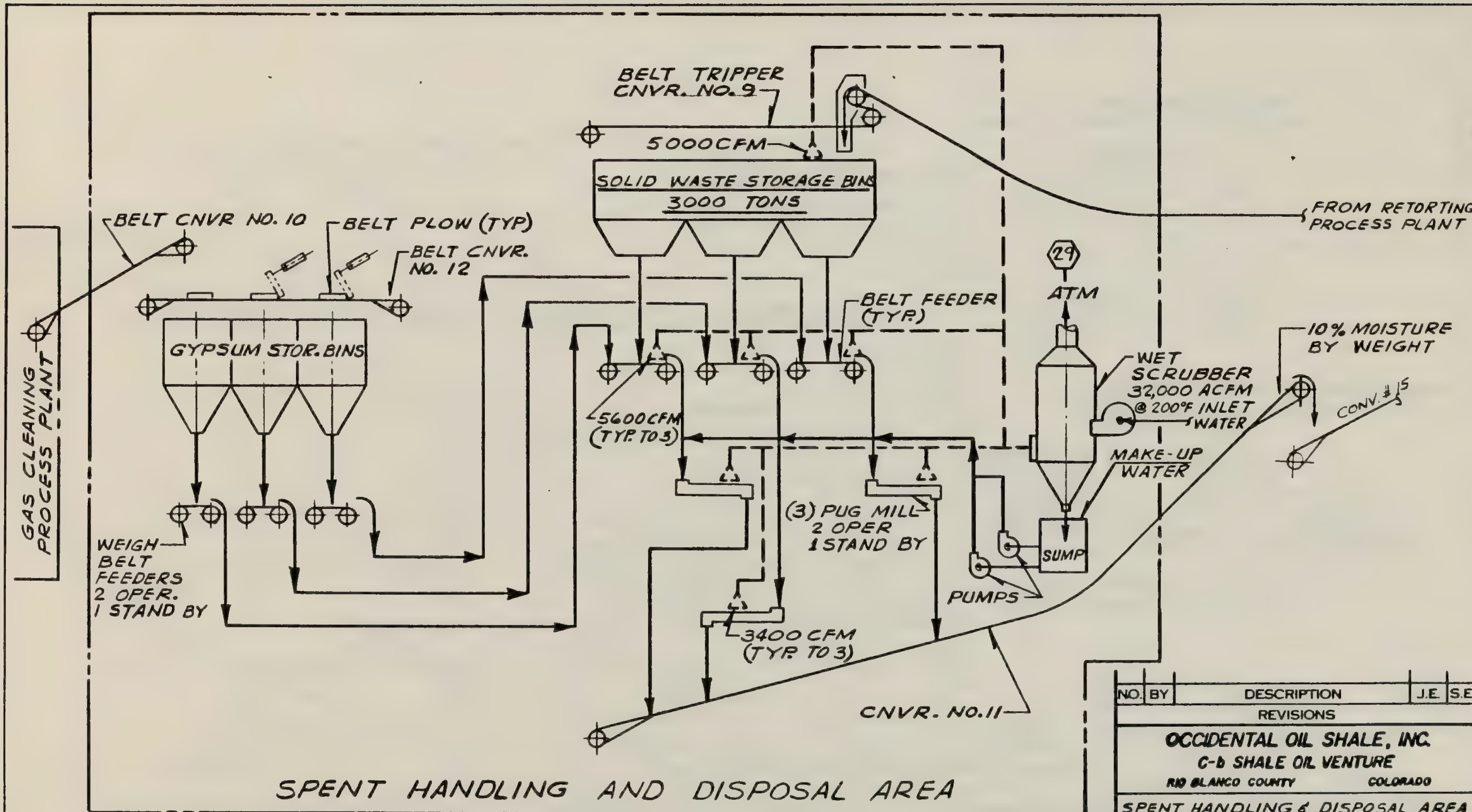
NO.	BY	DESCRIPTION	J.E.	S.E.
		REVISIONS		

OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO

TYPICAL INSERTABLE BAGHOUSE INSTALLATION

SCALE NONE DR WD 6-2-80 CH.
SECT. MECH J.E. S.E.
AREA APPD
Dravo DENVER OPERATIONS
CONTRACT NO. M-7541
DWG NO. MSK-10

ISSUE NO. 1 DATE PRINTED 9/25/80



NOTES
1. SAME NOTES AS MSK-2

NO.	BY	DESCRIPTION	J.E.	S.E.

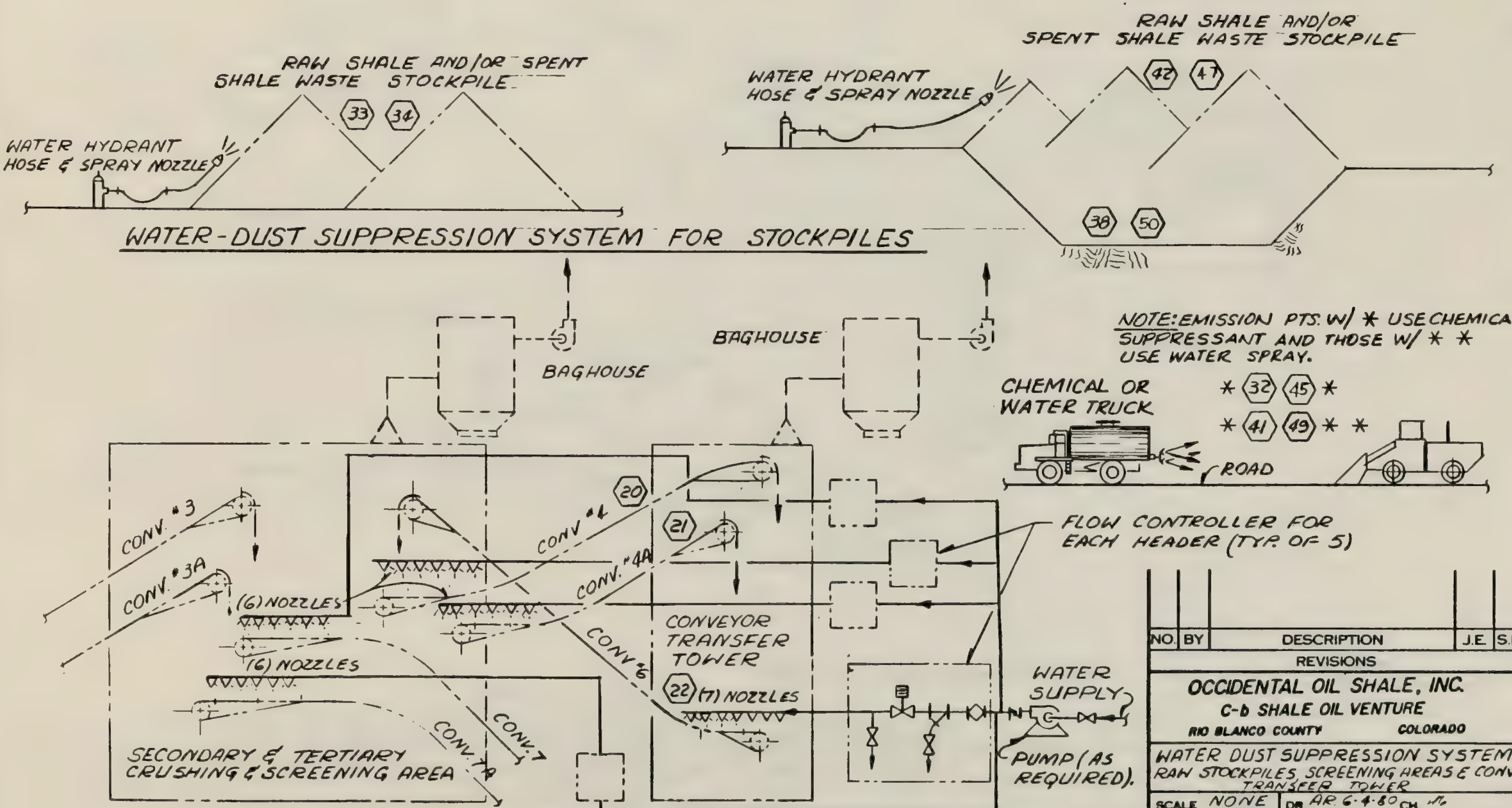
REVISIONS

OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO

SPENT HANDLING & DISPOSAL AREA
DUST CONTROL SYSTEM

SCALE NONE
SECT. MECH
AREA
DR. WO 5-28-80 CH.
J.E. S.E.
APPD
Dravo DENVER OPERATIONS
CONTRACT NO. M-7541
DWG NO MSK-11

ISSUE NO. 1 DATE PRINTED 9/25/80



WATER-DUST SUPPRESSION SYSTEM

NOTE:
1. SAME NOTES AS MSK-2.

ISSUE NO. 1 DATE PRINTED 9/25/80

NO.	BY	DESCRIPTION	J.E.	S.E.
		REVISIONS		

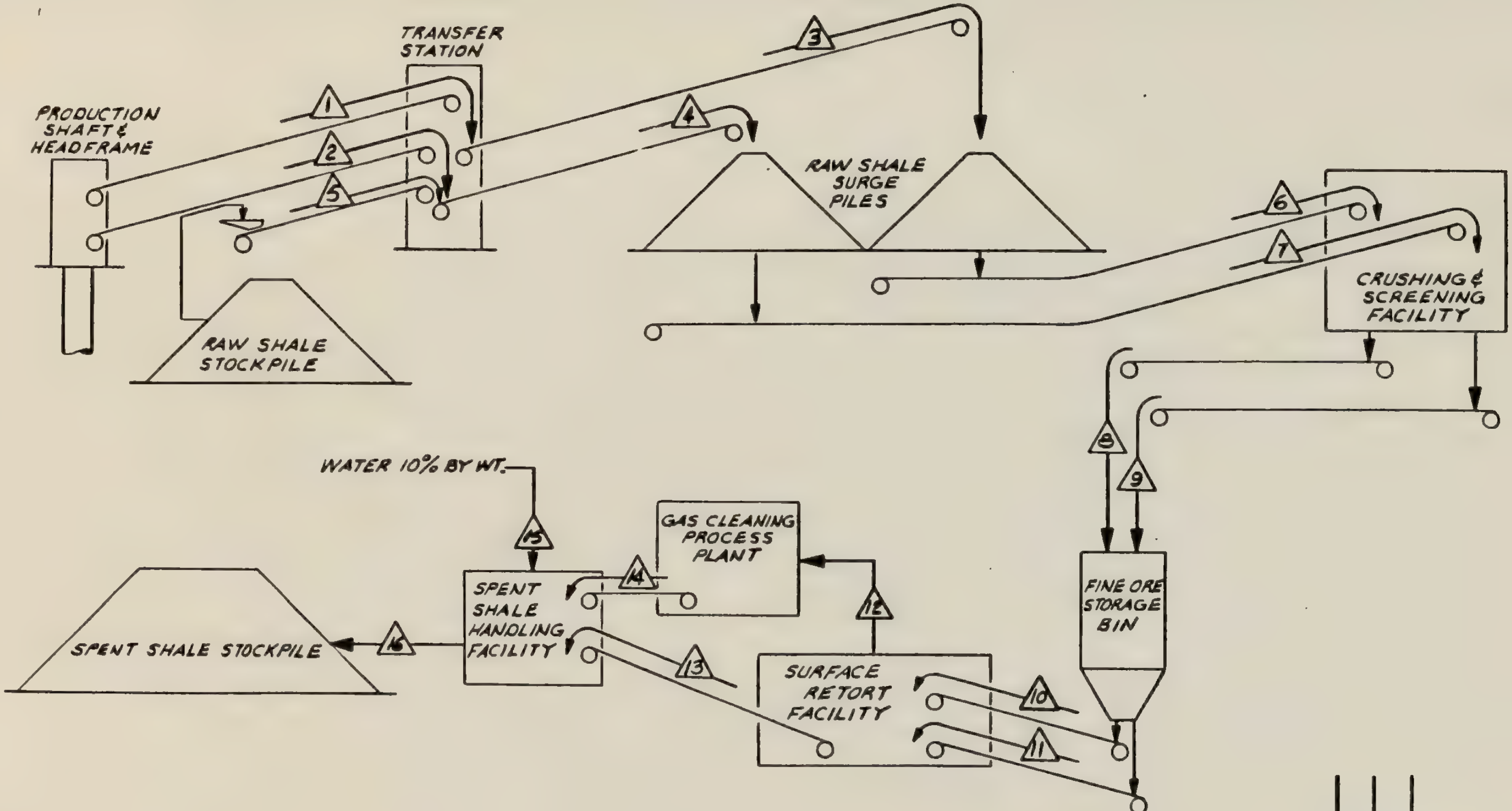
OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO

WATER DUST SUPPRESSION SYSTEM RAW STOCKPILES, SCREENING AREAS & CONV. TRANSFER TOWER

SCALE NONE DR. AR 6·4·80 CH.
SECT. MECH J.E. S.E.
AREA APPD.

Dravo DENVER OPERATIONS

CONTRACT NO. M-7541
DWG NO. MSK-12



ISSUE NO. 1 DATE PRINTED 9/25/80

MATERIAL BALANCE

STREAM NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TONS PER DAY	27,950	27,950	27,950	33,780	5830	30,865	30,865	30,865	30,865	30,865	30,865	14,880	46,850	1016	4685	52,700
PARTICLE SIZE	-8	-8	-8	-8	-8	-8	-8	-1/4	-1/4	-1/4	-1/4		-1/4			
MATERIAL	RAW SHALE	RAW SHALE	RAW SHALE	RAW SHALE	RAW SHALE	RAW SHALE	RAW SHALE	RAW SHALE	RAW SHALE	RAW SHALE	RAW SHALE	GAS & PROD.	SPENT SHALE	WET SLUDGE	WATER	SPENT SHALE

NO.	BY	DESCRIPTION	J.E.	S.E.

REVISIONS

OCCIDENTAL OIL SHALE, INC.
C-b SHALE OIL VENTURE
RIO BLANCO COUNTY COLORADO

MATERIAL BALANCE
SOLID MATERIAL HANDLING

SCALE NONE
SECT. MECH.
AREA 401
DR. R H CH A.
J.E. S.E.
APPD

Dravo
DENVER OPERATIONS

CONTRACT NO. M-7541
DWG NO. MSK-13

2.0

APPENDIX 2.0

Performance Data Sheets

APPENDIX 2.0

PERFORMANCE DATA SHEETS

TABLE OF CONTENTS

REV. 3 - 3-18-81 REV. 2 - 1-19-81 REV. 1 - 9-15-80

G-414
REV.11/62

Dravo
PITTSBURGH, PENNSYLVANIA

ENGINEERING COMPUTATIONS

EST NO.
CONT NO. M 7545
DIVISION DENVER

COMPANY OCCIDENTAL OIL SHALE, INC.
LOCATION RIO BLANCO COUNTY, COLORADO
DESCRIPTION AIR POLLUTION EMISSION SOURCE

DATE JUNE 2, 1980
DR E.K. CH LPG 6/20
REF

1.0 AIR POLLUTION DATA

EMISSION POINT: 3 (Ref. Dravo Drwg. No EM-101 Rev. D)
EMISSION SOURCE: Conveyor No 1 & 1A Transfer Point
PROPOSED CONTROL SYSTEM: Insertable Baghouse EFF. 99.5 %
POLLUTANT: Raw Shale, Point Source Dust
UNCONTROLLED EMISSION: 2.10 TPD 735.0 TPY
CONTROLLED EMISSION: 0.0105/0.315* TPD 3.67/110.3* TPY ②
EMISSION POINT GEOMETRY: TYPE Point
COORD. N183813.42; E1236122.27 ELEV. 6945'-0 A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	4000	ACFM	3103	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	184	LB/HR	6.92	GR/SCF
OUTLET DUST CONCENTRATION:	0.92	LB/HR	0.0346	GR/SCF
PER CENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT - ONE UNIT AT CONV. 1 & CONV. 1A (TOTAL TWO UNITS)

MAKE: DCE Vokes DALAMATIC Insertable Filter ③
MODEL: DLM-V20 type F ③
SIZE: 210 FT² FILTER AREA
NUMBER OF BAGS: 20
LENGTH OF BAGS: 3.33 FT.
WIDTH OF BAGS: 39.5 IN.
AIR TO CLOTH RATIO: 7.39:1 SCFM/ft²
DESIGN TEMPERATURE OF CLOTH: (polyester) 275 °F
METHOD OF BAG CLEAN: Reverse pulse jet type (100 psig)
PRESSURE DROP: 3 ± "W.G.
OVERALL COLLECTION EFFICIENCY: 99.5%
FREQUENCY OF CLEANING: As req'd. (Adjustable time interval: 6 to 30 sec)

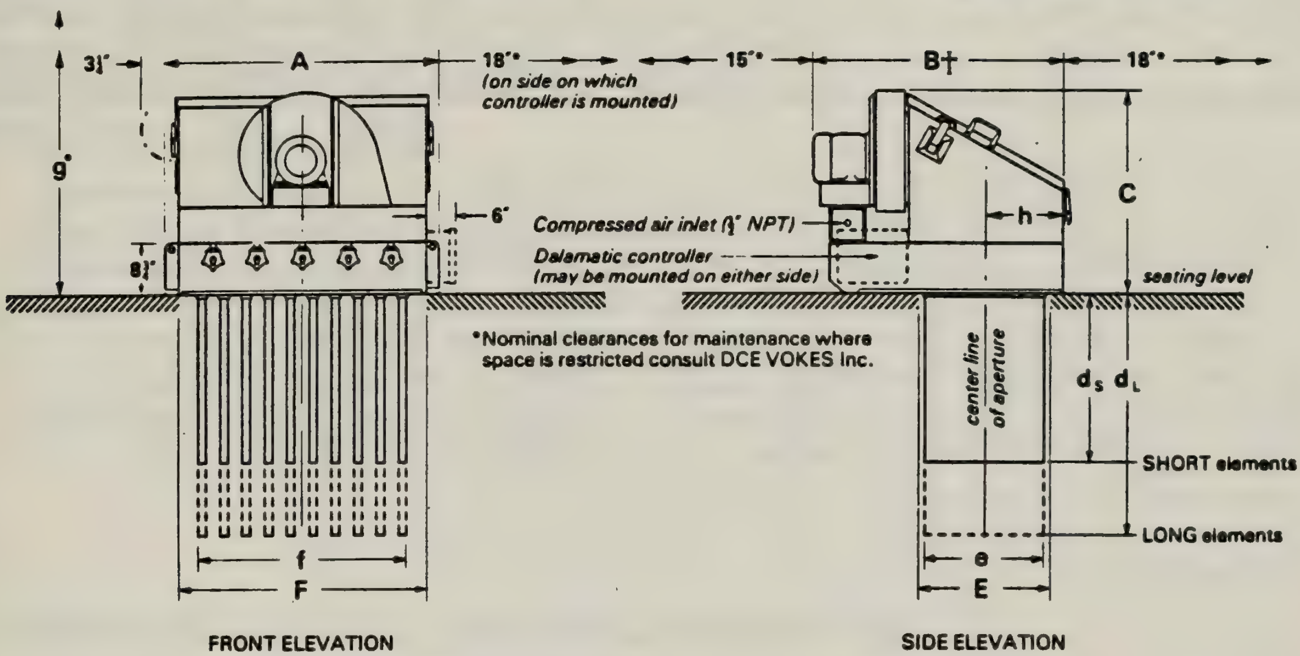
INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: DCE Vokes ③
MODEL Integral with filter unit
SIZE: -
SPEED 3600 RPM
CAPACITY: 2000 ACFM (EA. UNIT)
STATIC PRESSURE 5" W.G. ±
TYPE: Centrifugal
MOTOR SIZE: 7.5 (EA. UNIT) BHP

NOTES: ① PLANT Production: 117,275 BPD Shale Oil; 61,730 TPD rock.
② Figure with asterisk (*) applies to an alternate of using chemical spray at 85% efficiency.
③ or Equivalent.

Dalamatic Insertable Filter Series DLM-V, type F

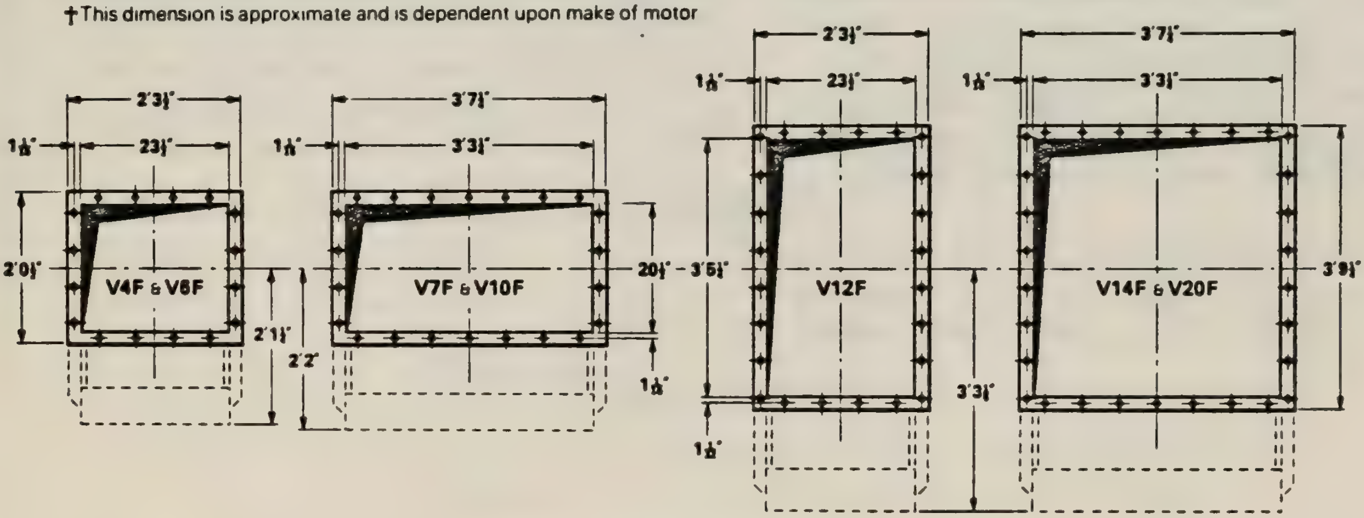
DCE VOKES



Size DLM-V7F illustrated, broken lines representing DLM-V10F

MODEL	Fan Motor h.p.	DIMENSIONS (Tolerance ±[illegible]" on main dimensions) A	B†	C	d_S	d_L	E	e	F	f	g*	h	Approx. net. weight
DLM-V4F	1	2'3[illegible]"	3'1[illegible]"	2'6[illegible]"	2'3[illegible]"	–	20[illegible]"	19"	23[illegible]"	18[illegible]"	3'7"	12[illegible]"	320 lb
DLM-V6F	1	2'3[illegible]"	3'1[illegible]"	2'6[illegible]"	–	3'3[illegible]"	20[illegible]"	19"	23[illegible]"	18[illegible]"	4'11"	12[illegible]"	350 lb
DLM-V7F	2	3'7[illegible]"	3'2[illegible]"	2'9[illegible]"	2'3[illegible]"	–	20[illegible]"	19"	3'3[illegible]"	2'8[illegible]"	3'7"	12[illegible]"	620 lb
DLM-V10F	2	3'7[illegible]"	3'2[illegible]"	2'9[illegible]"	–	3'3[illegible]"	20[illegible]"	19"	3'3[illegible]"	2'8[illegible]"	4'11"	12[illegible]"	670 lb
DLM-V12F	4	2'3[illegible]"	5'1[illegible]"	211"	–	3'3[illegible]"	3'5[illegible]"	3'3[illegible]"	23[illegible]"	18[illegible]"	4'11"	22[illegible]"	660 lb
DLM-V14F	4	3'7[illegible]"	5'1[illegible]"	2'11"	2'3[illegible]"	–	3'5[illegible]"	3'3[illegible]"	3'3[illegible]"	2'8[illegible]"	3'7"	22[illegible]"	850 lb
DLMV20F	5[illegible]	3'7[illegible]"	5'1[illegible]"	3'1"	–	3'3[illegible]"	3'5[illegible]"	3'3[illegible]"	3'3[illegible]"	2'8[illegible]"	4'11"	22[illegible]"	960 lb

†This dimension is approximate and is dependent upon make of motor



Aperture and mounting details

The Dalamatic Filter is designed to metric standards

All bolt holes are 11mm dia. ([illegible]") for 10mm ([illegible]") bolts with hole centres at 150mm (5[illegible]") pitch, and are symmetrical about center lines as shown above

SHEET 2

REV. 3 - 3-18-81 REV. 2 - 1-19-81 REV. 1 - 9-15-80

G-414 REV. 11/62

Dravo PITTSBURGH, PENNSYLVANIA

ENGINEERING COMPUTATIONS

EST NO. ____
CONT NO. M 7545
DIVISION DENVER

COMPANY OCCIDENTAL OIL SHALE, INC.
LOCATION RIO BLANCO COUNTY, COLORADO
DESCRIPTION AIR POLLUTION EMISSION SOURCE

DATE JUNE 2, 1980
DR E.K. CH LPG
REF 6/20

1.0 AIR POLLUTION DATA

EMISSION POINT: 4 (Ref. Dravo Drwg. № EM-101 Rev. C)
EMISSION SOURCE: Conveyor № 2 & 2A Transfer Points
PROPOSED CONTROL SYSTEM: Insertable Baghouse EFF. 99.5 %
POLLUTANT: Raw Shale, Point Source Dust
UNCONTROLLED EMISSION: 2.53 TPD 885.5 TPY
CONTROLLED EMISSION: 0.0126 / 0.38 * TPD 4.43/133.0 * TPY ②
EMISSION POINT GEOMETRY: TYPE Point
COORD. N 183 872.38; E 1236141.43 ELEV. 6945'-0 A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	4000	ACFM	3103	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	221	LB/HR	8.30	GR/SCF
OUTLET DUST CONCENTRATION:	1.105	LB/HR	0.0415	GR/SCF
PERCENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT - ONE UNIT AT CONV. 2 & CONV. 2A (TOTAL TWO UNITS)

MAKE: DCE Vokes DALMATIC Insertable Filter ③
MODEL: DLM-V20 type F ③
SIZE: 210 FT² FILTER AREA
NUMBER OF BAGS: 20
LENGTH OF BAGS: 3.33 FT.
WIDTH OF BAGS: 39.5 IN.
AIR TO CLOTH RATIO: 7.39:1 SCFM/ft²
DESIGN TEMPERATURE OF CLOTH: (polyester) 275 °F
METHOD OF BAG CLEAN: Reverse pulse jet type (100 psig)
PRESSURE DROP: 3± "W.G.
OVERALL COLLECTION EFFICIENCY: 99.5%
FREQUENCY OF CLEANING: As req'd. (Adjustable time interval: 6 to 30 sec)

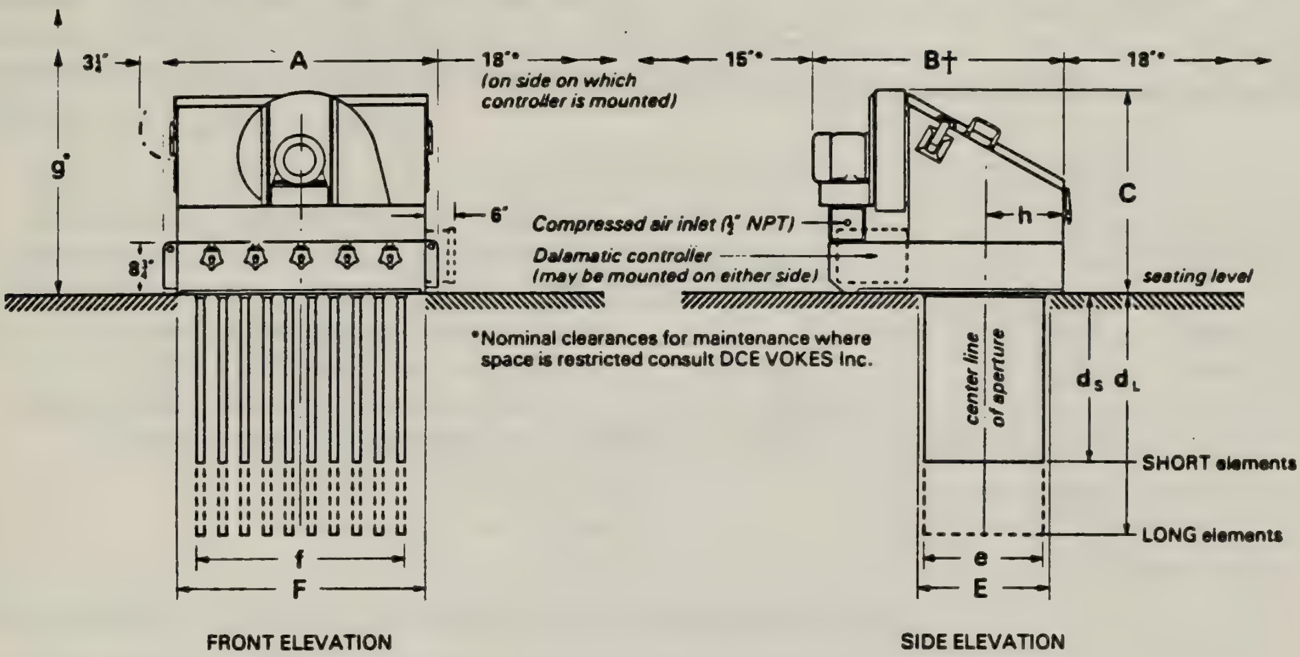
INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: DCE Vokes ③
MODEL Integral with filter Unit
SIZE:
SPEED 3600 RPM
CAPACITY: 2000 ACFM (EA. UNIT)
STATIC PRESSURE 5"W.G. ±
TYPE: Centrifugal
MOTOR SIZE: 7.5 (EA. UNIT) BHP.

NOTES: ① PLANT Production: 117,275 BPD Shale Oil; 61,730 TPD rock.
② Figure with asterisk (*) applies to an alternate of using chemical spray at 85% efficiency.
③ Or Equivalent.

Dalamatic Insertable Filter Series DLM-V, type F

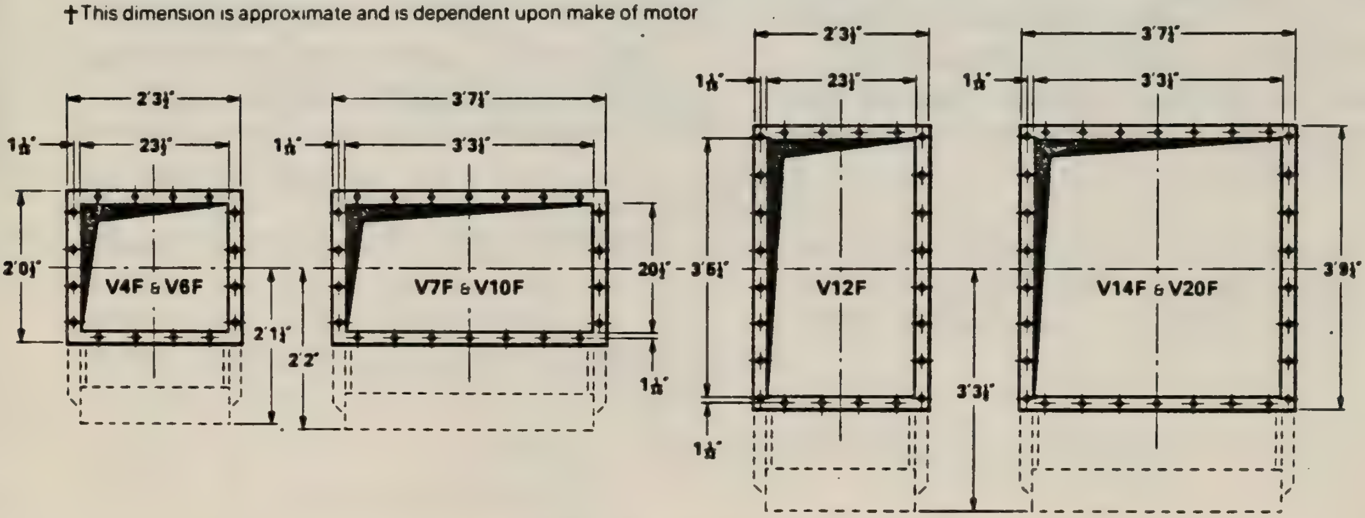
DCE VOKES



Size DLM-V7F illustrated, broken lines representing DLM-V10F

MODEL	Fan Motor h.p.	DIMENSIONS (Tolerance ±¼" on main dimensions) A	B†	C	d_S	d_L	E	e	F	f	g*	h	Approx. net. weight
DLM-V4F	1	2'3½"	3'1½"	2'6½"	2'3½"	–	20½"	19"	23½"	18½"	3'7"	12½"	320 lb
DLM-V6F	1	2'3½"	3'1½"	2'6½"	–	3'3½"	20½"	19"	23½"	18½"	4'11"	12½"	350 lb
DLM-V7F	2	3'7½"	3'2¾"	2'9½"	2'3½"	–	20½"	19"	3'3½"	2'8½"	3'7"	12½"	620 lb
DLM-V10F	2	3'7½"	3'2¾"	2'9½"	–	3'3½"	20½"	19"	3'3½"	2'8½"	4'11"	12½"	670 lb
DLM-V12F	4	2'3½"	5'1¾"	211"	–	3'3½"	3'5½"	3'3½"	23½"	18½"	4'11"	22¾"	660 lb
DLM-V14F	4	3'7½"	5'1¾"	2'11"	2'3½"	–	3'5½"	3'3½"	3'3½"	2'8½"	3'7"	22¾"	850 lb
DLMV20F	5½	3'7½"	5'1¾"	3'1"	–	3'3½"	3'5½"	3'3½"	3'3½"	2'8½"	4'11"	22¾"	960 lb

†This dimension is approximate and is dependent upon make of motor



Aperture and mounting details

The Dalamatic Filter is designed to metric standards

All bolt holes are 11mm dia. (⁷⁄₁₆") for 10mm (⅜") bolts with hole centres at 150mm (5²⁹⁄₃₂") pitch, and are symmetrical about center lines as shown above

SHEET 4

REV. 3- 3-18-81 REV. 2- 1-19-81 REV. 1- 9-15-80

G-414
REV. 11/62

Dravo PITTSBURGH, PENNSYLVANIA	ENGINEERING COMPUTATIONS	EST NO. CONT NO. M 7545 DIVISION DENVER
COMPANY OCCIDENTAL OIL SHALE, INC. LOCATION RIO BLANCO COUNTY, COLORADO DESCRIPTION AIR POLLUTION EMISSION SOURCE		DATE JUNE 2, 1980 DR E.K. CH LYG 6/20 REF

1.0 AIR POLLUTION DATA

EMISSION POINT: 7 (Ref. Dravo Drwg. Nº EM-101 Rev. D)

EMISSION SOURCE: Stacking Tower Load-in.

PROPOSED CONTROL SYSTEM: Baghouse EFF. 99.5 %

POLLUTANT: Raw Shale, Point Source Dust

UNCONTROLLED EMISSION: 1.27 TPD 444.5 TPY

CONTROLLED EMISSION: 0.006 TPD 2.1 TPY

EMISSION POINT GEOMETRY: TYPE Point

COORD. N182100.30; E1236605.67 ELEV. 6957'-0 A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	12500	ACFM	9694	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	110.4	LB/HR	1.33	GR/SCF
OUTLET DUST CONCENTRATION:	0.552	LB/HR	0.0066	GR/SCF
PERCENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT

MAKE: Pneumafil Reverse Air Dust Filter ② MODEL: 8.5-134-8 Walk-in type ②

SIZE: 1380 FT² FILTER AREA NUMBER OF BAGS: 134

LENGTH OF BAGS: 8.0 FT. DIAMETER OF BAGS: 4 5/8 IN.

AIR TO CLOTH RATIO: 7.02:1 SCFM/ft² DESIGN TEMPERATURE OF CLOTH: (polyester) 275 °F

METHOD OF BAG CLEAN: Reverse air (650 CFM @ 9 to 12" W.G.) PRESSURE DROP: 3" ± "W.G.

OVERALL COLLECTION EFFICIENCY: 99.5% FREQUENCY OF CLEANING: ONE/MIN. CYCLE

INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: Garden City Fan & Blower Co. ② MODEL RF-2 ②

SIZE: 21 SPEED 1400 RPM (Approx.)

CAPACITY: 12500 ACFM STATIC PRESSURE 12" W.G.

TYPE: Centrifugal Fan w/ Radial wheel

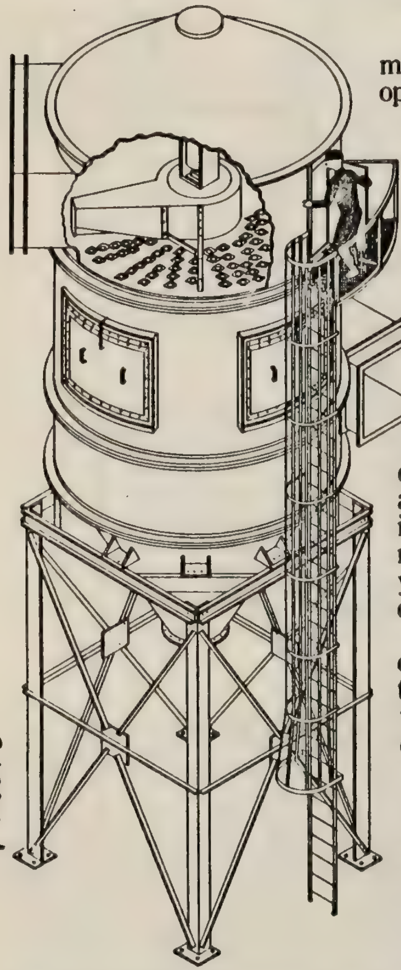
MOTOR SIZE: 50 BHP

NOTES: ① PLANT Production: 117,275 BPD Shale Oil; 61,730 TPD rock.

② OR Equivalent

SHEET NO. 5

Introducing The Only Dust Filter With A "Walk-In" Door On The Clean Air Plenum.



Recently, our research and development guys presented us with the opportunity to improve our dust filter system. A system that was already the most advanced in the industry. And since opportunities like that only knock once, we jumped on it like a duck on a june bug. We added a walk-in clean air plenum to our dust filter. No one else in the dust filtration business offers anything like it.

It makes inspection and maintenance simpler and safer than ever before. Because the plenum sits on top of our dust filter, in an enclosed, weatherproof chamber with a walk-in door and 8½ feet of standing room. So neither rain nor snow nor sleet nor dead of night will stay your maintenance man from the safe completion of his duty.

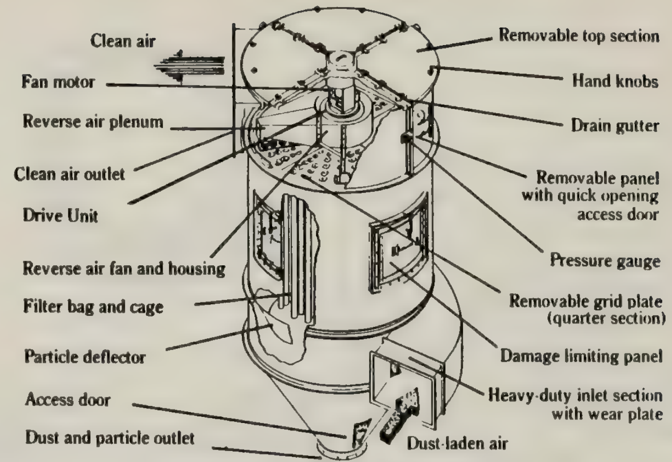
This new development was the only improvement we could think of to top the most advanced dust filter in the business. A filter that features easy installation, operation and maintenance.

So if our open door policy interests you, keep reading and you'll learn the fine details about the best dust filter on the market.

Standard Walk-In Mechanical Section Shown

Registered U.S. Patent Office.

SHEET 6



Optional Mechanical Section Shown

Construction and Features

Pneumafil Dust Filters, constructed of heavy gauge steel with a particle deflector and a heavy duty inlet section, are designed to provide simple, reliable air cleaning. These filters will provide for full compliance with Environmental Protection Agency and Occupational Safety and Health Act standards.

The newly designed sectional grid plates eliminate the dangerous and dirty task of bag changing from the entry side of the unit. Filter bags for the Pneumafil Dust Filter are loaded and replaced from the clean side of the unit—in a fraction of the time required for other systems. This innovation alone represents a significant saving in maintenance costs.

Incoming dust-laden air is first partially cleaned in the lower, entry section of the filter, forcing heavier particles to drop to the bottom of the hopper.

Air is then thoroughly filtered in the fabric filter bags and clean, conditioned air can be returned to the plant, if desired. No haphazard sequencing or cleaning. Each bag is cleaned once per revolution to insure maximum bag life.

Walk-in unit may be used as either positive or negative pressure unit. Withstands 17" w.g. negative pressure.

Reverse Air Cycle

Pneumafil's high-efficiency reverse air cycle provides once-a-minute cleaning of filter bags to maintain consistent filter porosity to assure efficient filtering action.

A rotating plenum covers each row of filter bags once a minute, reversing the normal direction of air flow. This action back flushes the bags and dislodges dust particles collected on the filter material which then fall to the bottom of the hopper for removal.

Installation

Pneumafil Dust Filters are shipped in from two to eight sections, depending on size. On-site installation requires merely bolting the sections together, a process requiring only six to eight man hours per section. Sprinkler heads, magnehelic gauge, damage limiting panels and complete reverse air fan and drive mechanism are factory installed. Bags are shipped on cages. No compressed air compressors, or valves are required. Filters are manufactured at Pneumafil's Charlotte, N.C. plant.

Maintenance

Regular maintenance of these units takes only minutes. Filter bags are installed and replaced from the clean side of the filter by simply loosening only two screws. Pneumafil's exclusive grid plate is constructed in four bolt-together sections for easy removal when necessary.

Damage limiting panels for added safety are standard on all Pneumafil Dust Filters. Operating instructions and lubrication schedules are also furnished to help you achieve maximum benefits. Other than routine bag maintenance, the only regular maintenance required is the lubrication of the gear box, the fan motor bearing, and the flanged motor support bearing.

Options

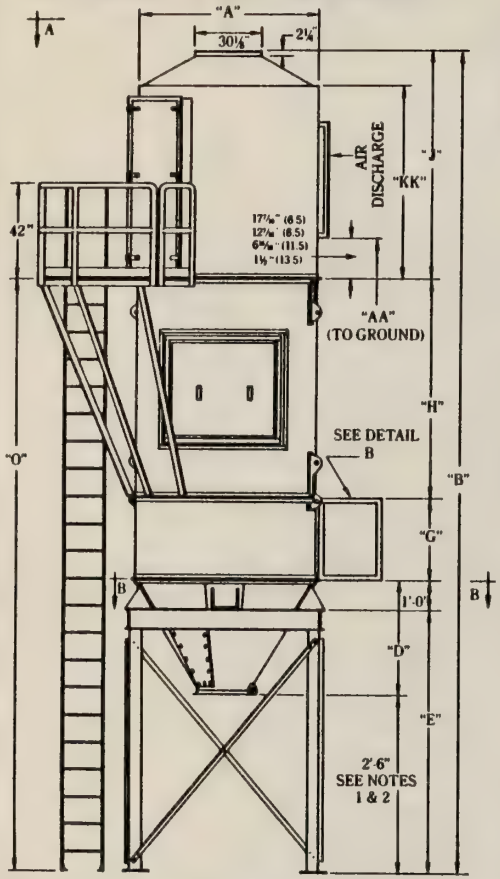
Available options for Pneumafil Dust Filters include:

- 3 types maintenance platforms:
  90° for bag replacement only.
  360° for complete maintenance accessibility.
  Access to damage limiting panels.
- Non-sparking wear plates.
- Variable-speed rotation for reverse air cycle.
- Air handling capacities for each diameter filter may be increased in the future with minimum inconvenience and expense.
- Explosion proof TEFC Motor for CL. II GR. G Application.

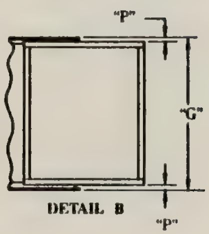
Pneumafil engineers are always available to assist you in either modifying our Dust Filters to your specific application or in a total air system design.

- Installed sprinkler heads are standard. Optional arrangement permits removal from outside of unit.

Dust Filter Specifications And Dimensions.



Standard Walk-In Mechanical Section Shown

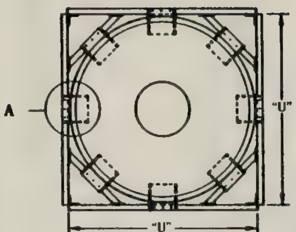


DETAIL B

NOTES:
1. For 4'-6" height (cone to ground), add 2'-0" to dimensions AA, B, E, & O.
2. For 6'-6" height (cone to ground, add 4'-0" to dimensions AA, B, E & O.
3. Entry section may be rotated 360° in approx. 6" increments except where it would interfere with ladder.
4. Discharge section & ladder may be rotated together 360° in approx. 6" increments except where they would interfere with the entry elbow.
5. Counterclockwise shown, clockwise opposite.

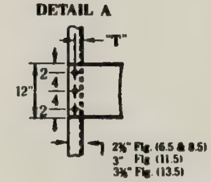
NOTE: DIMENSIONS AND SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

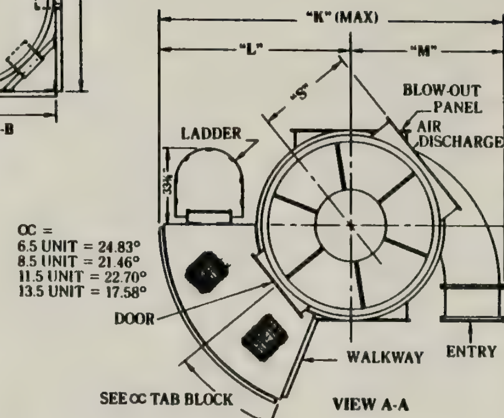
SEE DETAIL A



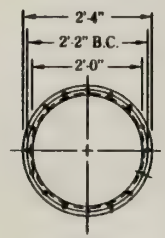
SECTION B-B

DETAIL A

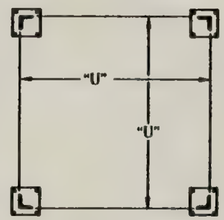




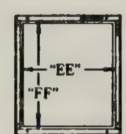
VIEW A-A



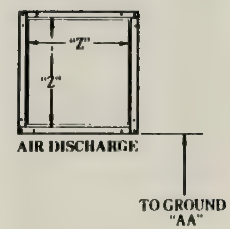
HOPPER OUTLET



FOUNDATION PLAN



AIR ENTRY



AIR DISCHARGE

*Actual brake horsepower shown. Motor frames are 254TC and 284TC respectively, to accommodate over-size bearings and shafts for added safety and equipment life.

FILTER SIZE	MEDIA AREA (SQ FT)	BLOWER MOTOR (BHP)*	DRIVE MOTOR (HP)	AIR TO MEDIA RATIO 5 TO 1 (C.F.M.)	AIR TO MEDIA RATIO 10 TO 1 (C.F.M.)	AIR TO MEDIA RATIO 15 TO 1 (C.F.M.)
6.5 92 4	474	8.5	1/4	2370	4740	7110
6.5 92 6	711	8.5	1/4	3555	7110	10665
6.5 92 8	948	8.5	1/4	4740	9480	14220
8.5 124 8	1277	8.5	1/4	6385	12770	19155
8.5 156 8	1607	8.5	1/4	8035	16070	24105
11.5 188 8	1936	17.6	1/4	9680	19360	29040
11.5 224 8	2307	17.6	1/4	11535	23070	34605
11.5 260 8	2678	17.6	1/4	13390	26780	40170
11.5 316 8	3255	17.6	1/4	16275	32550	48825
13.5-376-8	3873	17.6	1/4	19365	38730	58095
13.5 448 8	4614	17.6	1/4	23070	46140	69210

FILTER SIZE	DIM. A	DIM. B	DIM. D	DIM. E	DIM. G	DIM. H
6.5 92-4	6'-6"	21' 11 5/16"	4'-2 9/16"	5'-8 9/16"	3'-0"	4'-0"
6.5-92-6	6'-6"	23' 11 5/16"	4' 2 9/16"	5' 8 9/16"	3'-0"	6'-0"
6.5 92 8	6'-6"	25'-11 5/16"	4'-2 9/16"	5' 8 9/16"	3'-0"	8'-0"
8.5-124-8	8' 6"	28' 3 3/8"	5'-11 5/8"	7'-5 5/8"	3' 0"	8'-0"
8.5-156-8	8' 6"	28' 3 3/8"	5' 11 5/8"	7' 5 5/8"	3'-0"	8' 0"
11.5 188 8	11' 6"	32' 0 3/8"	8' 6 1/4"	10' 0 1/4"	4'-4"	8' 0"
11.5 224-8	11'-6"	32' 0 3/8"	8' 6 1/4"	10'-0 1/4"	4' 4"	8'-0"
11.5 260-8	11'-6"	32' 0 3/8"	8'-6 1/4"	10'-0 1/4"	4'-4"	8'-0"
11.5 316 8	11'-6"	32'-0 3/8"	8'-6 1/4"	10'-0 1/4"	4' 4"	8' 0"
13.5 376 8	13' 6"	35' 6 1/16"	10' 3 5/8"	11' 9 5/8"	5'-5"	8'-0"
13.5-448-8	13' 6"	35' 6 1/16"	10'-3 5/8"	11'-9 5/8"	5'-5"	8'-0"

DIM. J	DIM. K	DIM. L	DIM. M	DIM. N	DIM. O	DIM. P	DIM. S	DIM. T	DIM. U	DIM. Z	DIM. AA	DIM. EE	DIM. FF	DIM. KK
8' 2 1/4"	12'-8 3/8"	7'-0 3/8"	5'-8"	3' 3"	17'-4 13/16"	0	44 7/8"	1 3/16"	7'-0"	2' 8 1/4"	15'-2"	2'-0"	2'-8"	6'-11 1/4"
8'-2 1/4"	12' 8 3/8"	7'-0 3/8"	5'-8"	3'-3"	17'-6 13/16"	0	44 7/8"	1 3/16"	7'-0"	2'-8 1/4"	17' 2"	2'-0"	2'-8"	6'-11 1/4"
8'-2 1/4"	12' 8 3/8"	7'-0 3/8"	5'-8"	3' 3"	17'-8 13/16"	0	44 7/8"	1 3/16"	7' 0"	2'-8 1/4"	19' 2"	2'-0"	2'-8"	6'-11 1/4"
8'-9 1/4"	14'-8 3/8"	8'-0 3/8"	6'-8"	4'-3"	19'-5 7/8"	0	56 7/8"	1 3/16"	9'-0"	3' 6 1/4"	20' 6 1/16"	2'-10"	2'-8"	6'-11 1/4"
8' 9 1/4"	14' 8 3/8"	8' 0 3/8"	6' 8"	4' 3"	19' 5 7/8"	0	56 7/8"	1 3/16"	9' 0"	3' 6 1/4"	20'-6 1/16"	2' 10"	2' 8"	6' 11 1/4"
8' 8 1/8"	17' 8 3/8"	9'-6 1/8"	8' 2"	5' 9"	23' 4 5/16"	0	74 7/8"	1½"	12' 0"	4' 5 1/4"	23' 11 11/16"	3' 6"	4'-0"	5' 11 1/4"
8' 8 1/8"	17'-8 3/8"	9'-6 1/8"	8'-2'	5' 9"	23' 4 5/16"	0	74 7/8"	1½"	12' 0"	4'-5 1/4"	23' 11 11/16"	3' 6"	4'-0"	5' 11 1/4"
8' 8 1/8"	17'-8 3/8"	9'-6 1/8"	8' 2"	5'-9"	23' 4 5/16"	0	74 7/8"	1½"	12'-0"	4' 5 1/4"	23' 11 11/16"	3'-6"	4'-0"	5'-11 1/4"
8'-8 1/8"	17' 8 3/8"	9' 6 1/8"	8' 2"	5'-9"	23'-4 5/16"	0	74 7/8"	1½"	12'-0"	4' 5 1/4"	23' 11 11/16"	3' 6"	4'-0"	5'-11 1/4"
9' 3 9/16"	19' 8 3/8"	10' 6 7/8"	9' 2"	6'-9"	26' 2 7/8"	½	86 7/8"	1 11/16"	14' 0"	5' 4 1/4"	26' 4 1/8"	4'-0"	5'-0"	5'-11 15/16"
9'-3 9/16"	19'-8 3/8"	10'-6 7/8"	9'-2"	6'-9"	26'-2 7/8"	½	86 7/8"	1 11/16"	14'-0"	5'-4 1/4"	26'-4 1/8"	4'-0"	5'-0"	5'-11 15/16"

SHEET 7

REV. 3 - 3-18-81 REV. 2 - 1-19-81 REV. 1 - 9-15-80

G-414
REV. 11/62

Dravo PITTSBURGH, PENNSYLVANIA	ENGINEERING COMPUTATIONS	EST NO. ___ CONT NO. M 7545 DIVISION DENVER
COMPANY OCCIDENTAL OIL SHALE, INC. LOCATION RIO BLANCO COUNTY, COLORADO DESCRIPTION AIR POLLUTION EMISSION SOURCE		DATE JUNE 2, 1980 DR E.K. CH LPG 6/20 REF

1.0 AIR POLLUTION DATA

EMISSION POINT: 8 (Ref. Dravo Drwg. № EM-101 Rev D)

EMISSION SOURCE: Stacking Tower, Load-in

PROPOSED CONTROL SYSTEM: Baghouse EFF. 99.5 %

POLLUTANT: Raw Shale, Point Source Dust

UNCONTROLLED EMISSION: 1.27 TPD 444.5 TPY

CONTROLLED EMISSION: 0.006 TPD 2.1 TPY

EMISSION POINT GEOMETRY: TYPE Point

COORD. N182100.30; E1236605.67 ELEV. 6957'-0 A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	12500	ACFM	9694	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	110.4	LB/HR	1.33	GR/SCF
OUTLET DUST CONCENTRATION:	0.552	LB/HR	0.0066	GR/SCF
PERCENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT

MAKE: Pneumafil Reverse Air Dust Filter ②

MODEL: 8.5-134-8 Walk-in type ②

SIZE: 1380 FT² FILTER AREA

NUMBER OF BAGS: 134

LENGTH OF BAGS: 8.0 FT.

DIAMETER OF BAGS: 4 5/8 IN.

AIR TO CLOTH RATIO: 7.02:1 SCFM/ft²

DESIGN TEMPERATURE OF CLOTH: (polyester) 275 °F

METHOD OF BAG CLEAN: Reverse air (650 CFM @ 9 to 12" W.G.)

PRESSURE DROP: 3" ± "W.G.

OVERALL COLLECTION EFFICIENCY: 99.5%

FREQUENCY OF CLEANING: ONE/MIN. Cycle

INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: Garden City Fan & Blower Co. ②

MODEL RF3 ②

SIZE: 21

SPEED 1400 RPM (approx.)

CAPACITY: 12500 ACFM

STATIC PRESSURE 12" W.G.

TYPE: Centrifugal Fan w/Radial Wheel

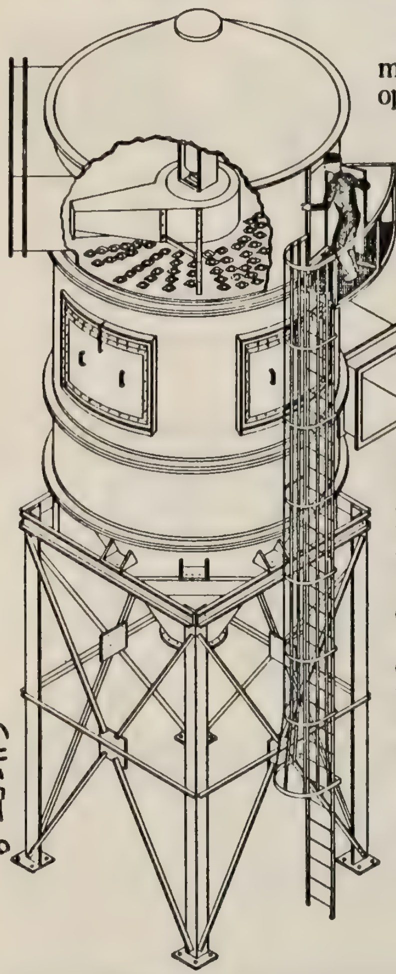
MOTOR SIZE: 50 BHP

NOTES: ① PLANT Production: 117,275 BPD Shale Oil; 61,730 TPD Rock.

② Or Equivalent

SHEET NO. 8

Introducing The Only Dust Filter With A "Walk-In" Door On The Clean Air Plenum.



Recently, our research and development guys presented us with the opportunity to improve our dust filter system. A system that was already the most advanced in the industry. And since opportunities like that only knock once, we jumped on it like a duck on a june bug. We added a walk-in clean air plenum to our dust filter. No one else in the dust filtration business offers anything like it.

It makes inspection and maintenance simpler and safer than ever before. Because the plenum sits on top of our dust filter, in an enclosed, weatherproof chamber with a walk-in door and 8½ feet of standing room. So neither rain nor snow nor sleet nor dead of night will stay your maintenance man from the safe completion of his duty.

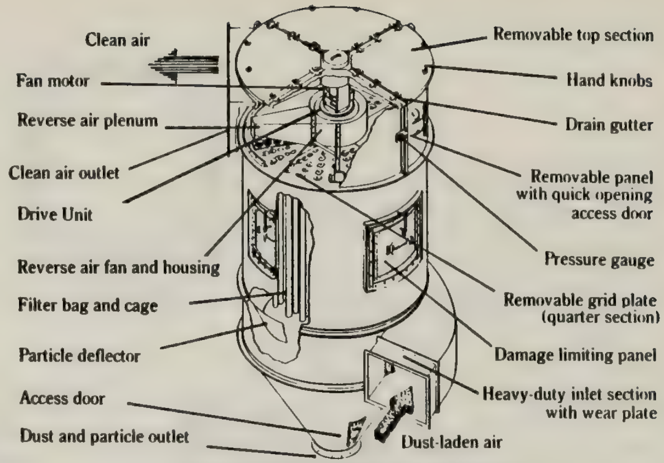
This new development was the only improvement we could think of to top the most advanced dust filter in the business. A filter that features easy installation, operation and maintenance.

So if our open door policy interests you, keep reading and you'll learn the fine details about the best dust filter on the market.

SHEET 9

Standard Walk-In Mechanical Section Shown

Registered U S Patent Office



Optional Mechanical Section Shown

Construction and Features

Pneumafil Dust Filters, constructed of heavy gauge steel with a particle deflector and a heavy duty inlet section, are designed to provide simple, reliable air cleaning. These filters will provide for full compliance with Environmental Protection Agency and Occupational Safety and Health Act standards.

The newly designed sectional grid plates eliminate the dangerous and dirty task of bag changing from the entry side of the unit. Filter bags for the Pneumafil Dust Filter are loaded and replaced from the clean side of the unit—in a fraction of the time required for other systems. This innovation alone represents a significant saving in maintenance costs.

Incoming dust-laden air is first partially cleaned in the lower, entry section of the filter, forcing heavier particles to drop to the bottom of the hopper.

Air is then thoroughly filtered in the fabric filter bags and clean, conditioned air can be returned to the plant, if desired. No haphazard sequencing or cleaning. Each bag is cleaned once per revolution to insure maximum bag life.

Walk-in unit may be used as either positive or negative pressure unit. Withstands 17" w.g. negative pressure.

Reverse Air Cycle

Pneumafil's high-efficiency reverse air cycle provides once-a-minute cleaning of filter bags to maintain consistent filter porosity to assure efficient filtering action.

A rotating plenum covers each row of filter bags once a minute, reversing the normal direction of air flow. This action back flushes the bags and dislodges dust particles collected on the filter material which then fall to the bottom of the hopper for removal.

Installation

Pneumafil Dust Filters are shipped in from two to eight sections, depending on size. On-site installation requires merely bolting the sections together, a process requiring only six to eight man hours per section. Sprinkler heads, magnehelic gauge, damage limiting panels and complete reverse air fan and drive mechanism are factory installed. Bags are shipped on cages. No compressed air compressors, or valves are required. Filters are manufactured at Pneumafil's Charlotte, N.C. plant.

Maintenance

Regular maintenance of these units takes only minutes. Filter bags are installed and replaced from the clean side of the filter by simply loosening only two screws. Pneumafil's exclusive grid plate is constructed in four bolt-together sections for easy removal when necessary.

Damage limiting panels for added safety are standard on all Pneumafil Dust Filters. Operating instructions and lubrication schedules are also furnished to help you achieve maximum benefits. Other than routine bag maintenance, the only regular maintenance required is the lubrication of the gear box, the fan motor bearing, and the flanged motor support bearing.

Options

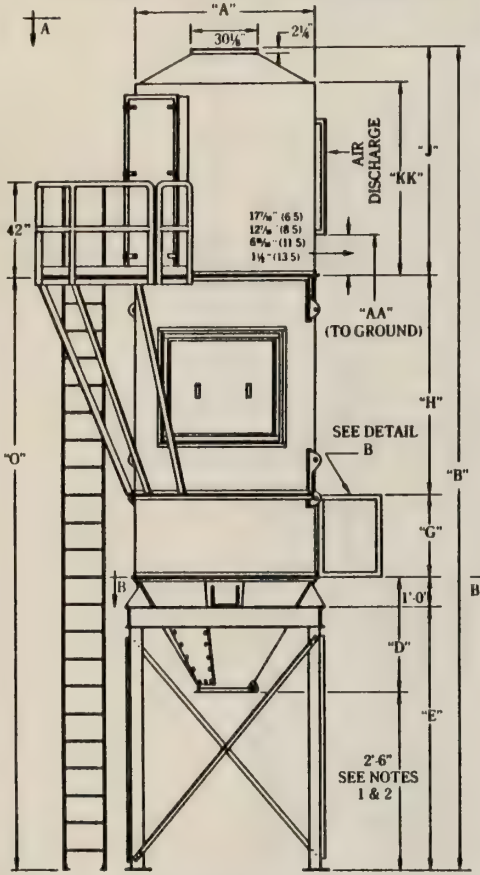
Available options for Pneumafil Dust Filters include:

- 3 types maintenance platforms:
  90° for bag replacement only.
  360° for complete maintenance accessibility.
  Access to damage limiting panels.
- Non-sparking wear plates.
- Variable-speed rotation for reverse air cycle.
- Air handling capacities for each diameter filter may be increased in the future with minimum inconvenience and expense.
- Explosion proof TEFC Motor for CL. II GR. G Application.

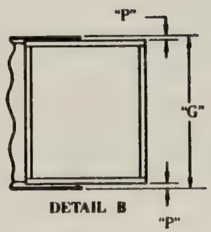
Pneumafil engineers are always available to assist you in either modifying our Dust Filters to your specific application or in a total air system design.

- Installed sprinkler heads are standard. Optional arrangement permits removal from outside of unit.

Dust Filter Specifications And Dimensions.

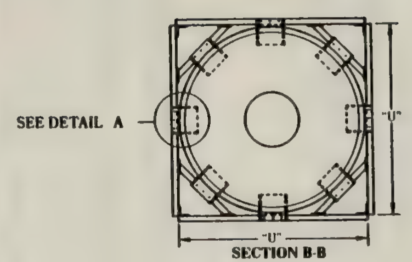


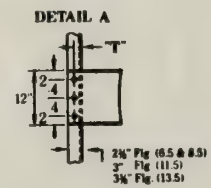
Standard Walk-In Mechanical Section Shown

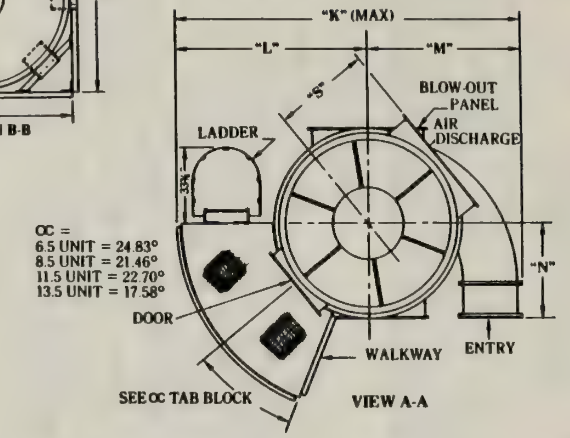


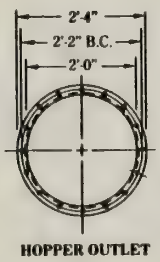
NOTES:
1. For 4'-6" height (cone to ground). add 2'-0" to dimensions AA, B, E, & O.
2. For 6'-6" height (cone to ground, add 4'-0" to dimensions AA, B, E & O.
3. Entry section may be rotated 360° in approx. 6" increments except where it would interfere with ladder.
4. Discharge section & ladder may be rotated together 360° in approx. 6" increments except where they would interfere with the entry elbow.
5. Counterclockwise shown, clockwise opposite.

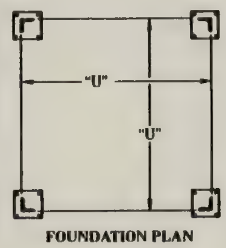
NOTE: DIMENSIONS AND SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

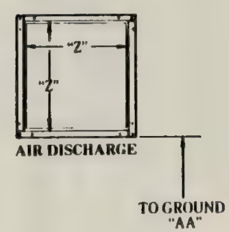












*Actual brake horsepower shown. Motor frames are 254TC and 284TC respectively, to accommodate over-size bearings and shafts for added safety and equipment life.

FILTER SIZE	MEDIA AREA (SQ FT)	BLOWER MOTOR (BHP)*	DRIVE MOTOR (HP)	AIR TO MEDIA RATIO 5 TO 1 (CFM)	AIR TO MEDIA RATIO 10 TO 1 (CFM)	AIR TO MEDIA RATIO 15 TO 1 (CFM)
6.5 92 4	474	8.5	1/4	2370	4740	7110
6.5 92 6	711	8.5	1/4	3555	7110	10665
6.5 92 8	948	8.5	1/4	4740	9480	14220
8.5 124 8	1277	8.5	1/4	6385	12770	19155
8.5 156 8	1607	8.5	1/4	8035	16070	24105
11.5 188 8	1936	17.6	1/4	9680	19160	29040
11.5 224 8	2307	17.6	1/4	11535	23070	34605
11.5 260 8	2678	17.6	1/4	13390	26780	40170
11.5 316 8	3255	17.6	1/4	16275	32550	48825
13.5 376 8	3873	17.6	1/4	19365	38730	58095
13.5 448 8	4614	17.6	1/4	23070	46140	69210

FILTER SIZE	DIM. A	DIM. B	DIM. D	DIM. E	DIM. G	DIM. H
6.5 92 4	6'-6"	21'-11 5/16"	4'-2 5/16"	5'-8 5/16"	3'-0"	4'-0"
6.5 92-6	6'-6"	23'-11 5/16"	4'-2 5/16"	5'-8 5/16"	3'-0"	6'-0"
6.5-92 8	6'-6"	25'-11 5/16"	4'-2 5/16"	5'-8 5/16"	3'-0"	8'-0"
8.5 124 8	8'-6"	28'-3 1/8"	5'-11 1/8"	7'-5 5/8"	3'-0"	8'-0"
8.5 156 8	8'-6"	28'-3 1/8"	5'-11 1/8"	7'-5 5/8"	3'-0"	8'-0"
11.5-188 8	11'-6"	32'-0 7/8"	8'-6 1/4"	10'-0 1/4"	4'-4"	8'-0"
11.5 224 8	11'-6"	32'-0 7/8"	8'-6 1/4"	10'-0 1/4"	4'-4"	8'-0"
11.5 260 8	11'-6"	32'-0 7/8"	8'-6 1/4"	10'-0 1/4"	4'-4"	8'-0"
11.5 316 8	11'-6"	32'-0 7/8"	8'-6 1/4"	10'-0 1/4"	4'-4"	8'-0"
13.5 376 8	13'-6"	35'-6 5/16"	10'-3 3/8"	11'-9 5/8"	5'-5"	8'-0"
13.5 448-8	13'-6"	35'-6 5/16"	10'-3 3/8"	11'-9 5/8"	5'-5"	8'-0"

DIM. J	DIM. K	DIM. L	DIM. M	DIM. N	DIM. O	DIM. P	DIM. S	DIM. T	DIM. U	DIM. Z	DIM. AA	DIM. EE	DIM. FF	DIM. KK
8'-2 1/4"	12'-8 1/8"	7'-0 1/4"	5'-8"	3'-3"	17'-4 13/16"	0	44 3/8"	1 5/16"	7'-0"	2'-8 1/4"	15'-2"	2'-0"	2'-8"	6'-11 1/4"
8'-2 1/4"	12'-8 1/8"	7'-0 1/4"	5'-8"	3'-3"	17'-6 13/16"	0	44 3/8"	1 5/16"	7'-0"	2'-8 1/4"	17'-2"	2'-0"	2'-8"	6'-11 1/4"
8'-2 1/4"	12'-8 1/8"	7'-0 1/4"	5'-8"	3'-3"	17'-8 13/16"	0	44 3/8"	1 5/16"	7'-0"	2'-8 1/4"	19'-2"	2'-0"	2'-8"	6'-11 1/4"
8'-9 1/4"	14'-8 1/8"	8'-0 1/4"	6'-8"	4'-3"	19'-5 3/8"	0	56 3/8"	1 5/16"	9'-0"	3'-6 1/4"	20'-6 1/16"	2'-10"	2'-8"	6'-11 1/4"
8'-9 1/4"	14'-8 1/8"	8'-0 1/4"	6'-8"	4'-3"	19'-5 3/8"	0	56 3/8"	1 5/16"	9'-0"	3'-6 1/4"	20'-6 1/16"	2'-10"	2'-8"	6'-11 1/4"
8'-8 1/16"	17'-8 1/8"	9'-6 1/4"	8'-2"	5'-9"	23'-4 5/16"	0	74 3/8"	1 1/2"	12'-0"	4'-5 1/4"	23'-11 11/16"	3'-6"	4'-0"	5'-11 1/4"
8'-8 1/16"	17'-8 1/8"	9'-6 1/4"	8'-2"	5'-9"	23'-4 5/16"	0	74 3/8"	1 1/2"	12'-0"	4'-5 1/4"	23'-11 11/16"	3'-6"	4'-0"	5'-11 1/4"
8'-8 1/16"	17'-8 1/8"	9'-6 1/4"	8'-2"	5'-9"	23'-4 5/16"	0	74 3/8"	1 1/2"	12'-0"	4'-5 1/4"	23'-11 11/16"	3'-6"	4'-0"	5'-11 1/4"
8'-8 1/16"	17'-8 1/8"	9'-6 1/4"	8'-2"	5'-9"	23'-4 5/16"	0	74 3/8"	1 1/2"	12'-0"	4'-5 1/4"	23'-11 11/16"	3'-6"	4'-0"	5'-11 1/4"
9'-3 5/16"	19'-8 3/8"	10'-6 3/4"	9'-2"	6'-9"	26'-2 7/8"	1/2	86 7/8"	1 11/16"	14'-0"	5'-4 1/4"	26'-4 1/8"	4'-0"	5'-0"	5'-11 13/16"
9'-3 5/16"	19'-8 3/8"	10'-6 3/4"	9'-2"	6'-9"	26'-2 7/8"	1/2	86 7/8"	1 11/16"	14'-0"	5'-4 1/4"	26'-4 1/8"	4'-0"	5'-0"	5'-11 13/16"

SHEET 10

REV. 3 - 3-18-81 REV. 2 - 1-19-81 REV. 1 - 9-15-80

G-414
REV. 11/62

Dravo PITTSBURGH, PENNSYLVANIA	ENGINEERING COMPUTATIONS	EST NO. ; CONT NO. M 7545 ; DIVISION DENVER
COMPANY OCCIDENTAL OIL SHALE, INC. ; LOCATION RIO BLANCO COUNTY, COLORADO ; DESCRIPTION AIR POLLUTION EMISSION SOURCE		DATE JUNE 2, 1980 ; DR E.K. CH LPG ; REF 6/20

1.0 AIR POLLUTION DATA

EMISSION POINT: 9 (Ref. Dravo Drwg. No EM-101 Rev. D)
EMISSION SOURCE: Stacking Tower, Load-in, - Coarse Shale Storage
PROPOSED CONTROL SYSTEM: Baghouse EFF. 99.5 %
POLLUTANT: Raw Shale, Point Source Dust.
UNCONTROLLED EMISSION: 1.05 TPD 367.5 TPY
CONTROLLED EMISSION: 0.005 TPD 1.75 TPY
EMISSION POINT GEOMETRY: TYPE Point
COORD. N181998.16; E1236405.23 ELEV. 6957'-0" A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	12500	ACFM	9694	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	92.2	LB/HR	1.11	GR/SCF
OUTLET DUST CONCENTRATION:	0.461	LB/HR	0.0056	GR/SCF
PERCENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT

MAKE: Pneumafil Reverse Air Dust Filter ② MODEL: 8.5-134-8 Walk-in type ②
SIZE: 1380 FT² FILTER AREA NUMBER OF BAGS: 134
LENGTH OF BAGS: 8.0 FT. DIAMETER OF BAGS: 4 5/8 IN.
AIR TO CLOTH RATIO: 7.02:1 SCFM/ft² DESIGN TEMPERATURE OF CLOTH: (polyester) 275 °F
METHOD OF BAG CLEAN: Reverse air (650 CFM @ 9 to 12 "W.G.) PRESSURE DROP: 3 ± "W.G.
OVERALL COLLECTION EFFICIENCY: 99.5% FREQUENCY OF CLEANING: one / min. Cycle.

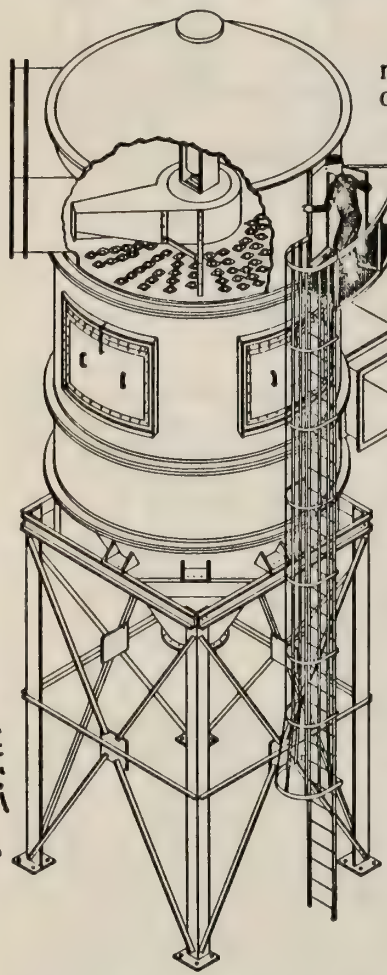
INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: Garden City Fan & Blower Co. ② MODEL RF-2 ②
SIZE: 21 SPEED 1400 RPM (approx)
CAPACITY: 12500 ACFM STATIC PRESSURE 12" W.G.
TYPE: Centrifugal Fan w/ Radial Wheel
MOTOR SIZE: 50 BHP.

NOTES: ① PLANT Production: 117,275 BPD Shale Oil; 61,730 TPD rock.
② or Equivalent.

SHEET NO. 11

Introducing The Only Dust Filter With A "Walk-In" Door On The Clean Air Plenum.



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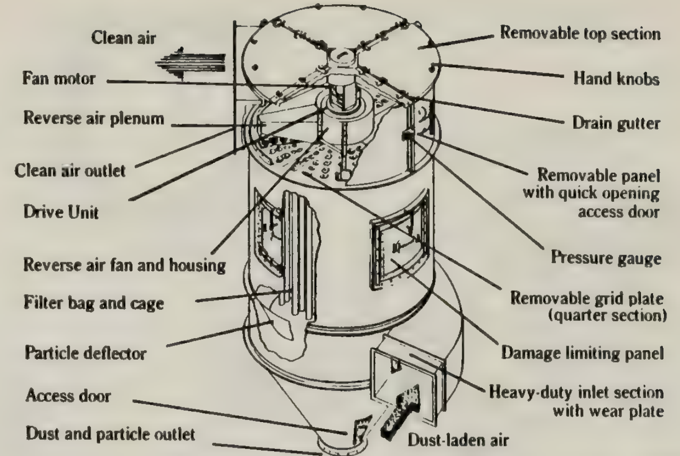
Standard Walk-In Mechanical Section Shown

Registered U.S. Patent Office



Optional Mechanical Section Shown

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The newly designed sectional grid plates eliminate the dangerous and dirty task of bag changing from the entry side of the unit. Filter bags for the Pneumafil Dust Filter are loaded and replaced from the clean side of the unit—in a fraction of the time required for other systems. This innovation alone represents a significant saving in maintenance costs.

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Walk-in unit may be used as either positive or negative pressure unit. Withstands 17" w.g. negative pressure.

Reverse Air Cycle

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Installation

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Maintenance

Regular maintenance of these units takes only minutes. Filter bags are installed and replaced from the clean side of the filter by simply loosening only two screws. Pneumafil's exclusive grid plate is constructed in four bolt-together sections for easy removal when necessary.

Damage limiting panels for added safety are standard on all Pneumafil Dust Filters. Operating instructions and lubrication schedules are also furnished to help you achieve maximum benefits. Other than routine bag maintenance, the only regular maintenance required is the lubrication of the gear box, the fan motor bearing, and the flanged motor support bearing.

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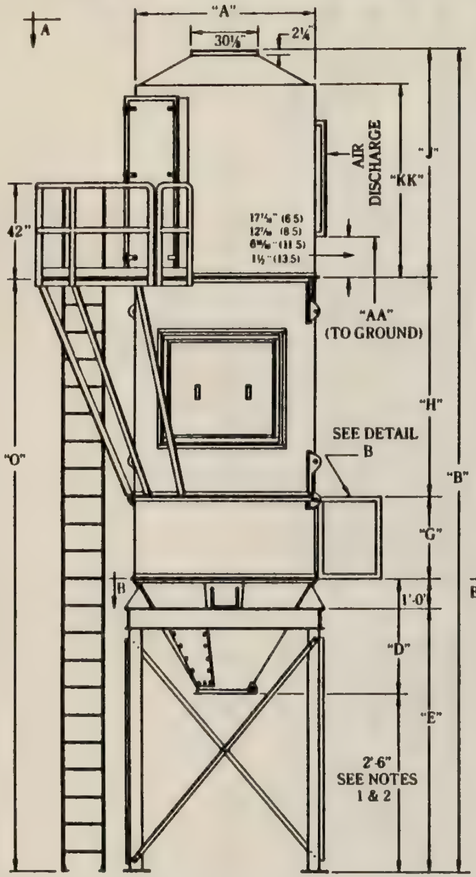
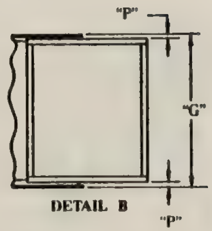
- Installed sprinkler heads are standard. Optional arrangement permits removal from outside of unit.

SHEET 12

Dust Filter Specifications And Dimensions.



Standard Walk-In Mechanical Section Shown



DETAIL B

NOTES:
1. For 4'-6" height (cone to ground), add 2'-0" to dimensions AA, B, E, & O.
2. For 6'-6" height (cone to ground, add 4'-0" to dimensions AA, B, E & O.
3. Entry section may be rotated 360° in approx. 6" increments except where it would interfere with ladder.
4. Discharge section & ladder may be rotated together 360° in approx. 6" increments except where they would interfere with the entry elbow.
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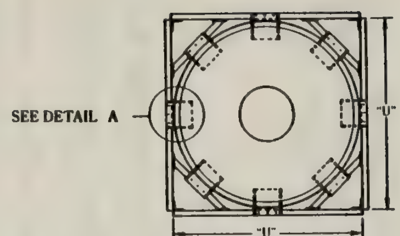
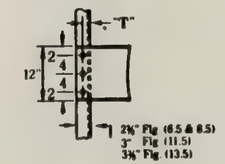
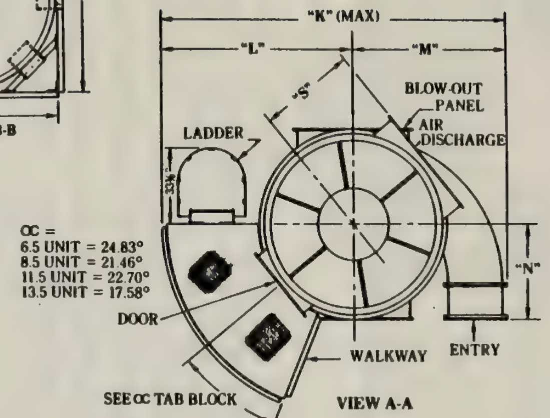
NOTE: DIMENSIONS AND SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.



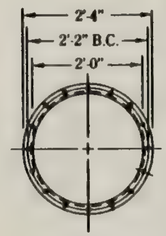
SECTION B-B



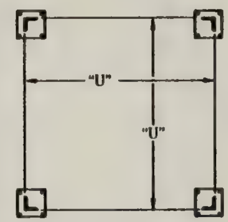
DETAIL A



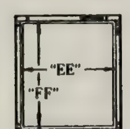
VIEW A-A



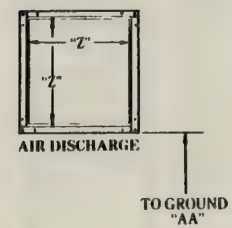
HOPPER OUTLET



FOUNDATION PLAN



AIR ENTRY



AIR DISCHARGE

*Actual brake horsepower shown. Motor frames are 254TC and 284TC respectively, to accommodate over-size bearings and shafts for added safety and equipment life.

FILTER SIZE	MEDIA AREA (SQ FT)	BLOWER MOTOR (BHP)*	DRIVE MOTOR (HP)	AIR TO MEDIA RATIO 5 TO 1 (CFM)	AIR TO MEDIA RATIO 10 TO 1 (CFM)	AIR TO MEDIA RATIO 15 TO 1 (CFM)
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8.5 156.8	1607	8.5	1/4	8035	16070	24105
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11.5 224.8	2307	17.6	1/4	11535	23070	34605
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11.5 316.8	3255	17.6	1/4	16275	32550	48825
13.5 376.8	3873	17.6	1/4	19365	38730	58095
13.5 448.8	4614	17.6	1/4	23070	46140	69210

FILTER SIZE	DIM. A	DIM B	DIM. D	DIM. E	DIM. G	DIM. H
6.5 92-4	6'6"	21'-11 5/16"	4'2 7/16"	5'-8 7/16"	3'0"	4'-0"
6.5 92 6	6'6"	23'-11 5/16"	4'2 7/16"	5'8 7/16"	3'0"	6'0"
6.5 92 8	6'-6"	25'11 5/16"	4'2 7/16"	5'8 7/16"	3'-0"	8'0"
8.5 124-8	8'-6"	28'3⅛"	5'-11⅝"	7'5⅝"	3'0"	8'-0"
8.5-156 8	8'6"	28'3⅛"	5'-11⅝"	7'-5⅝"	3'0"	8'0"
11.5 188-8	11'6"	32'0⅞"	8'-6¼"	10'-0¼"	4'4"	8'0"
11.5 224-8	11'-6"	32'0⅞"	8'-6¼"	10'-0¼"	4'4"	8'0"
11.5 260 8	11'-6"	32'0⅞"	8'6¼"	10'0¼"	4'-4"	8'-0"
11.5 316 8	11'6"	32'0⅞"	8'6¼"	10'-0¼"	4'4"	8'0"
13.5 376-8	13'6"	35'-6 1/16"	10'-3⅜"	11'-9⅜"	5'5"	8'0"
13.5-448 8	13'6"	35'6 1/16"	10'3⅜"	11'-9⅜"	5'5"	8'-0"

DIM. J	DIM. K	DIM. L	DIM. M	DIM N	DIM. O	DIM. P	DIM. S	DIM. T	DIM. U	DIM Z	DIM. AA	DIM. EE	DIM. FF	DIM KK
8'-2¼"	12'8⅝"	7'-0⅜"	5'-8"	3'-3"	17'4 11/16"	0	44¾"	1 3/16"	7'-0"	2'-8¼"	15'2"	2'0"	2'8"	6'-11¼"
8'-2¼"	12'8⅝"	7'0⅜"	5'8"	3'-3"	17'6 11/16"	0	44¾"	1 3/16"	7'0"	2'-8¼"	17'2"	2'0"	2'8"	6'11¼"
8'-2¼"	12'8⅝"	7'0⅜"	5'8"	3'-3"	17'-8 11/16"	0	44¾"	1 3/16"	7'0"	2'8¼"	19'2"	2'-0"	2'-8"	6'-11¼"
8'9¼"	14'8⅝"	8'-0⅜"	6'-8"	4'3"	19'5⅞"	0	56⅞"	1 3/16"	9'0"	3'6¼"	20'6 1/16"	2'10"	2'8"	6'11¼"
8'-9¼"	14'8⅝"	8'0⅜"	6'-8"	4'3"	19'5⅞"	0	56⅞"	1 3/16"	9'0"	3'6¼"	20'6 1/16"	2'10"	2'8"	6'11¼"
8'-8⅛"	17'8⅝"	9'6⅜"	8'-2"	5'-9"	23'4 3/16"	0	74⅜"	1½"	12'0"	4'5¼"	23'11 11/16"	3'6"	4'0"	5'11¼"
8'-8⅛"	17'8⅝"	9'6⅜"	8'-2'	5'9"	23'4 3/16"	0	74⅜"	1½"	12'0"	4'5¼"	23'11 11/16"	3'6"	4'0"	5'11¼"
8'8⅛"	17'8⅝"	9'-6⅜"	8'2"	5'9"	23'-4 3/16"	0	74⅜"	1½"	12'0"	4'-5¼"	23'11 11/16"	3'6"	4'0"	5'11¼"
8'-8⅛"	17'8⅝"	9'6⅜"	8'2"	5'9"	23'4 3/16"	0	74⅜"	1½"	12'0"	4'5¼"	23'11 11/16"	3'6"	4'0"	5'11¼"
9'3 9/16"	19'8⅞"	10'6⅞"	9'-2"	6'9"	26'2⅞"	½	86⅞"	1 11/16"	14'0"	5'4⅛"	26'4⅛"	4'0"	5'0"	5'11 13/16"
9'3 9/16"	19'8⅞"	10'6⅞"	9'2"	6'9"	26'2⅞"	½	86⅞"	1 11/16"	14'0"	5'-4⅛"	26'4⅛"	4'0"	5'0"	5'-11 13/16"

SHEET 13

G-414
REV.11/62

REV. 3 - 3-18-81 REV. 2 - 1-19-81 REV. 1 - 9-15-80

Dravo PITTSBURGH, PENNSYLVANIA

ENGINEERING COMPUTATIONS

EST NO. ____
CONT NO. M 7545
DIVISION DENVER

COMPANY OCCIDENTAL OIL SHALE, INC.
LOCATION RIO BLANCO COUNTY, COLORADO
DESCRIPTION AIR POLLUTION EMISSION SOURCE

DATE JUNE 2, 1980
DR E.K. CH LPG 6/20
REF ____

1.0 AIR POLLUTION DATA

EMISSION POINT: 10 (Ref.: Dravo Drwg. Nº EM-101 Rev. D)
EMISSION SOURCE: Stacking Tower, Load-in - Coarse Shale Storeage
PROPOSED CONTROL SYSTEM: Baghouse EFF. 99.5 %
POLLUTANT: Raw shale, Point Source Dust
UNCONTROLLED EMISSION: 1.05 TPD 367.5 TPY
CONTROLLED EMISSION: 0.005 TPD 1.75 TPY
EMISSION POINT GEOMETRY: TYPE Point
COORD. N181998.16; E1236405.23 ELEV. 6957'-0 A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	12500	ACFM	9694	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	92.2	LB/HR	1.11	GR/SCF
OUTLET DUST CONCENTRATION:	0.461	LB/HR	0.0056	GR/SCF
PER CENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT

MAKE: Pneumafil Reverse Air Dust Filter ②
MODEL: 8.5-134-8 Walk-in type ②
SIZE: 1380 FT² FILTER AREA
NUMBER OF BAGS: 134
LENGTH OF BAGS: 8.0 FT.
DIAMETER OF BAGS: 4 2/3 IN.
AIR TO CLOTH RATIO: 7.02:1 SCFM/ft²
DESIGN TEMPERATURE OF CLOTH: (polyester) 275 °F
METHOD OF BAG CLEAN: Reverse air (650 CFM @ 9 to 12" W.G.)
PRESSURE DROP: 3± "W.G.
OVERALL COLLECTION EFFICIENCY: 99.5%
FREQUENCY OF CLEANING: one/min Cycle

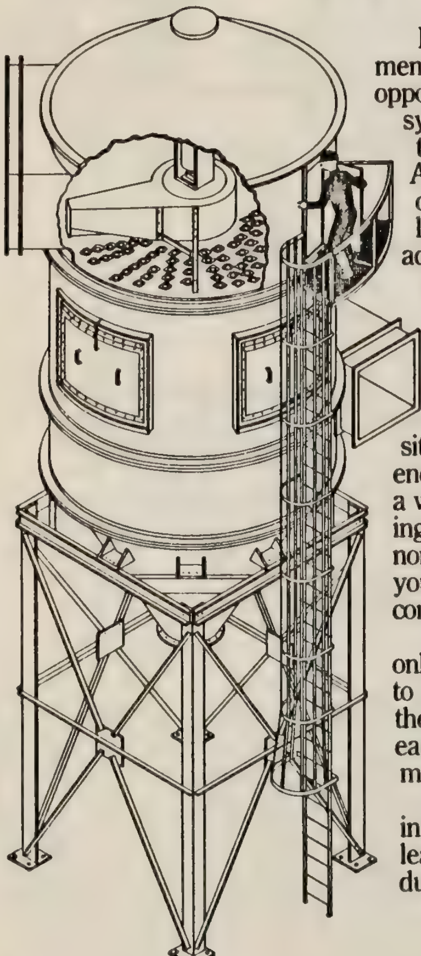
INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: Garden City Fan & Blower Co. ②
MODEL RF-2 ②
SIZE: 21
SPEED 1400 RPM (approx)
CAPACITY: 12500 ACFM
STATIC PRESSURE 12" W.G.
TYPE: Centrifugal Fan w/Radial Wheel
MOTOR SIZE: 50 BHP

NOTES: ① PLANT Production: 117,275 BPD Shale Oil; 61,730 TPD rock.
② or Equivalent.

SHEET NO. 14

Introducing The Only Dust Filter With A "Walk-In" Door On The Clean Air Plenum.



Recently, our research and development guys presented us with the opportunity to improve our dust filter system. A system that was already the most advanced in the industry. And since opportunities like that only knock once, we jumped on it like a duck on a june bug. We added a walk-in clean air plenum to our dust filter. No one else in the dust filtration business offers anything like it.

It makes inspection and maintenance simpler and safer than ever before. Because the plenum sits on top of our dust filter, in an enclosed, weatherproof chamber with a walk-in door and 8½ feet of standing room. So neither rain nor snow nor sleet nor dead of night will stay your maintenance man from the safe completion of his duty.

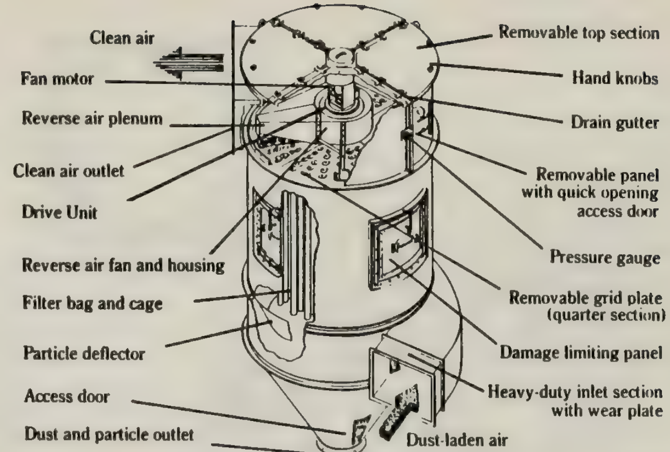
This new development was the only improvement we could think of to top the most advanced dust filter in the business. A filter that features easy installation, operation and maintenance.

So if our open door policy interests you, keep reading and you'll learn the fine details about the best dust filter on the market.

Standard Walk-In Mechanical Section Shown

Registered U.S. Patent Office

SHEET 15



Optional Mechanical Section Shown

Construction and Features

Pneumafil Dust Filters, constructed of heavy gauge steel with a particle deflector and a heavy duty inlet section, are designed to provide simple, reliable air cleaning. These filters will provide for full compliance with Environmental Protection Agency and Occupational Safety and Health Act standards.

The newly designed sectional grid plates eliminate the dangerous and dirty task of bag changing from the entry side of the unit. Filter bags for the Pneumafil Dust Filter are loaded and replaced from the clean side of the unit—in a fraction of the time required for other systems. This innovation alone represents a significant saving in maintenance costs.

Incoming dust-laden air is first partially cleaned in the lower, entry section of the filter, forcing heavier particles to drop to the bottom of the hopper.

Air is then thoroughly filtered in the fabric filter bags and clean, conditioned air can be returned to the plant, if desired. No haphazard sequencing or cleaning. Each bag is cleaned once per revolution to insure maximum bag life.

Walk-in unit may be used as either positive or negative pressure unit. Withstands 17" w.g. negative pressure.

Reverse Air Cycle

Pneumafil's high-efficiency reverse air cycle provides once-a-minute cleaning of filter bags to maintain consistent filter porosity to assure efficient filtering action.

A rotating plenum covers each row of filter bags once a minute, reversing the normal direction of air flow. This action back flushes the bags and dislodges dust particles collected on the filter material which then fall to the bottom of the hopper for removal.

Installation

Pneumafil Dust Filters are shipped in from two to eight sections, depending on size. On-site installation requires merely bolting the sections together, a process requiring only six to eight man hours per section. Sprinkler heads, magnehelic gauge, damage limiting panels and complete reverse air fan and drive mechanism are factory installed. Bags are shipped on cages. No compressed air compressors, or valves are required. Filters are manufactured at Pneumafil's Charlotte, N.C. plant.

Maintenance

Regular maintenance of these units takes only minutes. Filter bags are installed and replaced from the clean side of the filter by simply loosening only two screws. Pneumafil's exclusive grid plate is constructed in four bolt-together sections for easy removal when necessary.

Damage limiting panels for added safety are standard on all Pneumafil Dust Filters. Operating instructions and lubrication schedules are also furnished to help you achieve maximum benefits. Other than routine bag maintenance, the only regular maintenance required is the lubrication of the gear box, the fan motor bearing, and the flanged motor support bearing.

Options

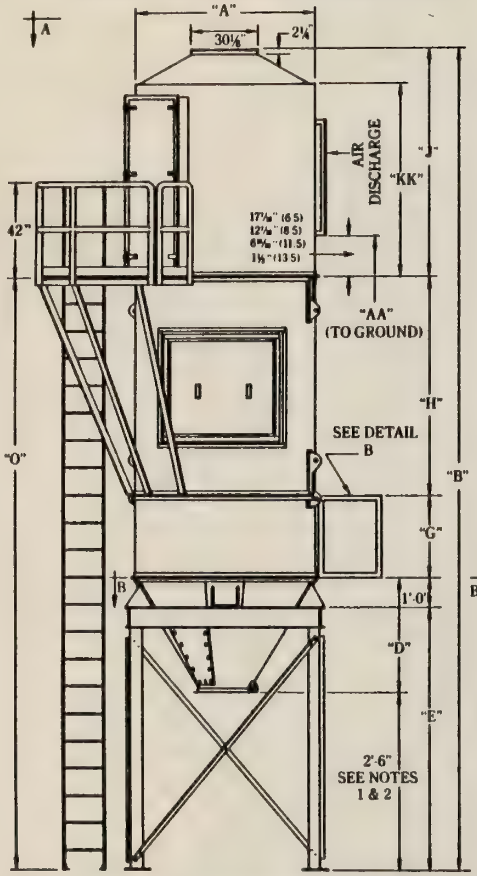
Available options for Pneumafil Dust Filters include:

- 3 types maintenance platforms:
  90° for bag replacement only.
  360° for complete maintenance accessibility.
  Access to damage limiting panels.
- Non-sparking wear plates.
- Variable-speed rotation for reverse air cycle.
- Air handling capacities for each diameter filter may be increased in the future with minimum inconvenience and expense.
- Explosion proof TEFC Motor for CL. II GR. G Application.

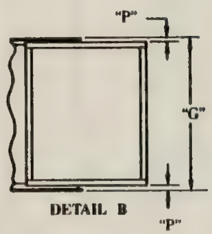
Pneumafil engineers are always available to assist you in either modifying our Dust Filters to your specific application or in a total air system design.

- Installed sprinkler heads are standard. Optional arrangement permits removal from outside of unit.

Dust Filter Specifications And Dimensions.



Standard Walk-In Mechanical Section Shown

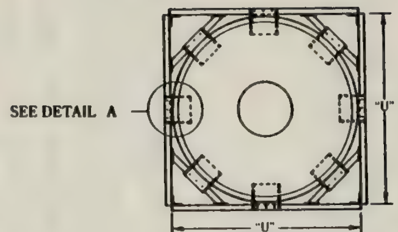


DETAIL B

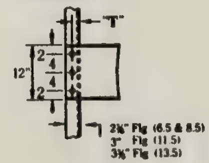
NOTES:

1. For 4'-6" height (cone to ground), add 2'-0" to dimensions AA, B, E, & O.
2. For 6'-6" height (cone to ground, add 4'-0" to dimensions AA, B, E & O.
3. Entry section may be rotated 360° in approx. 6" increments except where it would interfere with ladder.
4. Discharge section & ladder may be rotated together 360° in approx. 6" increments except where they would interfere with the entry elbow.
5. Counterclockwise shown, clockwise opposite.

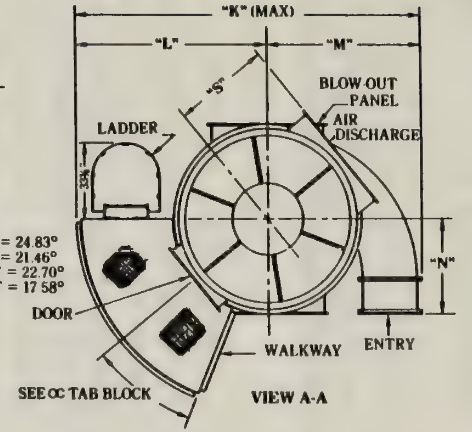
NOTE: DIMENSIONS AND SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.



SECTION B-B

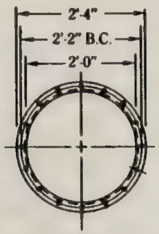


DETAIL A

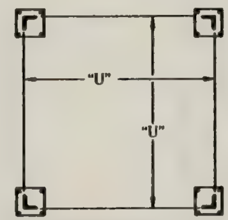


CC =
6.5 UNIT = 24.83°
8.5 UNIT = 21.46°
11.5 UNIT = 22.70°
13.5 UNIT = 17.58°

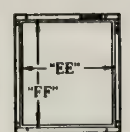
VIEW A-A



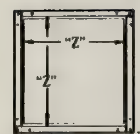
HOPPER OUTLET



FOUNDATION PLAN



AIR ENTRY



AIR DISCHARGE

TO GROUND "AA"

FILTER SIZE	MEDIA AREA (SQ FT)	BLOWER MOTOR (BHP)*	DRIVE MOTOR (H P)	AIR TO MEDIA RATIO 5 TO 1 (C F M)	AIR TO MEDIA RATIO 10 TO 1 (C F M)	AIR TO MEDIA RATIO 15 TO 1 (C F M)
6.5 92 4	474	8.5	1/4	2370	4740	7110
6.5 92 6	711	8.5	1/4	3555	7110	10665
6.5 92 8	948	8.5	1/4	4740	9480	14220
8.5 124 8	1277	8.5	1/4	6385	12770	19155
8.5 156 8	1607	8.5	1/4	8035	16070	24105
11.5 188 8	1936	17.6	1/4	9680	19360	29040
11.5 224 8	2307	17.6	1/4	11535	23070	34605
11.5 260 8	2678	17.6	1/4	13390	26780	40170
11.5 316 8	3255	17.6	1/4	16275	32550	48825
13.5 376 8	3873	17.6	1/4	19365	38730	58095
13.5 448 8	4614	17.6	1/4	23070	46140	69210

FILTER SIZE	DIM. A	DIM. B	DIM. D	DIM. E	DIM. G	DIM. H
6.5 92 4	6'6"	21'-11 5/16"	4'2 9/16"	5'8 9/16"	3'-0"	4'0"
6.5 92 6	6'6"	23'11 5/16"	4'2 9/16"	5'-8 9/16"	3'0"	6'0"
6.5-92 8	6'-6"	25'11 5/16"	4'-2 9/16"	5'8 9/16"	3'-0"	8'-0"
8.5 124-8	8'6"	28'3⅜"	5'-11⅝"	7'-5⅝"	3'-0"	8'0"
8.5 156 8	8'6"	28'3⅜"	5'11⅝"	7'-5⅝"	3'0"	8'0"
11.5-188 8	11'6"	32'0⅞"	8'-6¼"	10'-0¼"	4'-4"	8'0"
11.5 224 8	11'6"	32'0⅞"	8'-6¼"	10'0¼"	4'-4"	8'-0"
11.5 260 8	11'-6"	32'-0⅞"	8'-6¼"	10'-0¼"	4'-4"	8'0"
11.5 316-8	11'6"	32'0⅞"	8'-6¼"	10'-0¼"	4'-4"	8'-0"
13.5 376 8	13'-6"	35'6 1/16"	10'-3⅜"	11'9⅝"	5'5"	8'-0"
13.5-448 8	13'6"	35'6 1/16"	10'3⅜"	11'-9⅝"	5'-5"	8'-0"

*Actual brake horsepower shown. Motor frames are 254TC and 284TC respectively, to accommodate over-size bearings and shafts for added safety and equipment life.

DIM. J	DIM. K	DIM. L	DIM. M	DIM. N	DIM. O	DIM. P	DIM. S	DIM. T	DIM. U	DIM. Z	DIM. AA	DIM. EE	DIM. FF	DIM. KK
8'-2¼"	12'-8⅜"	7'-0⅜"	5'-8"	3'-3"	17'-4 13/16"	0	44⅞"	1 1/16"	7'-0"	2'8¼"	15'2"	2'-0"	2'8"	6'-11¼"
8'2¼"	12'8⅜"	7'-0⅜"	5'8"	3'-3"	17'-6 13/16"	0	44⅞"	1 1/16"	7'0"	2'8¼"	17'2"	2'-0"	2'8"	6'-11¼"
8'-2¼"	12'8⅜"	7'0⅜"	5'8"	3'-3"	17'8 13/16"	0	44⅞"	1 1/16"	7'0"	2'-8¼"	19'-2"	2'-0"	2'-8"	6'-11¼"
8'-9¼"	14'-8⅜"	8'-0⅜"	6'-8"	4'-3"	19'-5⅞"	0	56⅞"	1 1/16"	9'-0"	3'-6¼"	20'6 1/16"	2'10"	2'8"	6'11¼"
8'9¼"	14'8⅜"	8'0⅜"	6'8"	4'-3"	19'-5⅞"	0	56⅞"	1 1/16"	9'0"	3'-6¼"	20'6 1/16"	2'10"	2'8"	6'-11¼"
8'8⅛"	17'8⅜"	9'6⅜"	8'-2"	5'9"	23'-4 5/16"	0	74⅞"	1½"	12'0"	4'5¼"	23'11 11/16"	3'6"	4'0"	5'11¼"
8'8⅛"	17'8⅜"	9'6⅜"	8'-2'	5'9"	23'4 5/16"	0	74⅞"	1½"	12'0"	4'5¼"	23'11 11/16"	3'6"	4'0"	5'11¼"
8'-8⅛"	17'8⅜"	9'6⅜"	8'2"	5'9"	23'4 5/16"	0	74⅞"	1½"	12'0"	4'5¼"	23'11 11/16"	3'-6"	4'0"	5'-11¼"
8'8⅛"	17'8⅜"	9'-6⅜"	8'2"	5'-9"	23'4 5/16"	0	74⅞"	1½"	12'-0"	4'5¼"	23'11 11/16"	3'-6"	4'0"	5'-11¼"
9'3 9/16"	19'8⅞"	10'6⅞"	9'2"	6'9"	26'2⅞"	½	86⅞"	1 11/16"	14'0"	5'4¼"	26'-4⅛"	4'-0"	5'0"	5'11 13/16"
9'-3 9/16"	19'-8⅞"	10'6⅞"	9'-2"	6'9"	26'2⅞"	½	86⅞"	1 11/16"	14'-0"	5'-4¼"	26'4⅛"	4'-0"	5'0"	5'-11 13/16"

SHEET 16

REV. 2 - 3-18-81, REV. 1- 1-19-81

G-414
REV. 11/62

Dravo
PITTSBURGH, PENNSYLVANIA

ENGINEERING COMPUTATIONS

EST NO. ______
CONT NO. M 7541
DIVISION DENVER

COMPANY OCCIDENTAL OIL SHALE, INC.
LOCATION RIO BLANCO COUNTY, COLORADO
DESCRIPTION AIR POLLUTION EMISSION SOURCE

DATE 9-15-80
DR WG CH ______
REF ______

1.0 AIR POLLUTION DATA

EMISSION POINT: 13 (REF. DRAVO DRWG. NO. EM-101 REV. D).
EMISSION SOURCE: CONV. NO. 14 TRANSF. PT. @ TRANSFER TOWER
PROPOSED CONTROL SYSTEM: INSERTABLE BAGHOUSE EFF. 99.5 %
POLLUTANT: RAW SHALE FUGITIVE DUST - POINT SOURCE
UNCONTROLLED EMISSION: 0.437 TPD 152.95 TPY
CONTROLLED EMISSION: 0.002/0.066* TPD 0.70/23.1* TPY ②
EMISSION POINT GEOMETRY: TYPE POINT
COORD. N183,872.38; E123,141.43 ELEV. 6945-0

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	2000	ACFM	1553	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	36.4	LB/HR	2.74	GR/SCF
OUTLET DUST CONCENTRATION:	1.82	LB/HR	0.0137	GR/SCF
PERCENT MOISTURE:	NEGLIGIBLE	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT

MAKE: DCE VOKES DALAMATIC INSERTABLE FILTER ③ MODEL: DLM-V20 TYPE F ③
SIZE: 210 FT² FILTER AREA NUMBER OF BAGS: 20
LENGTH OF BAGS: 3.33 FT. WIDTH OF BAGS: 39.5 IN.
AIR TO CLOTH RATIO: 7.39:1 SCFM/FT DESIGN TEMPERATURE OF CLOTH: (POLYESTER) 275 °F
METHOD OF BAG CLEAN: REVERSE PULSE JET TYPE (100 PSIG) PRESSURE DROP: 3 ± "W.G.
OVERALL COLLECTION EFFICIENCY: 99.5% FREQUENCY OF CLEANING: AS REQD.

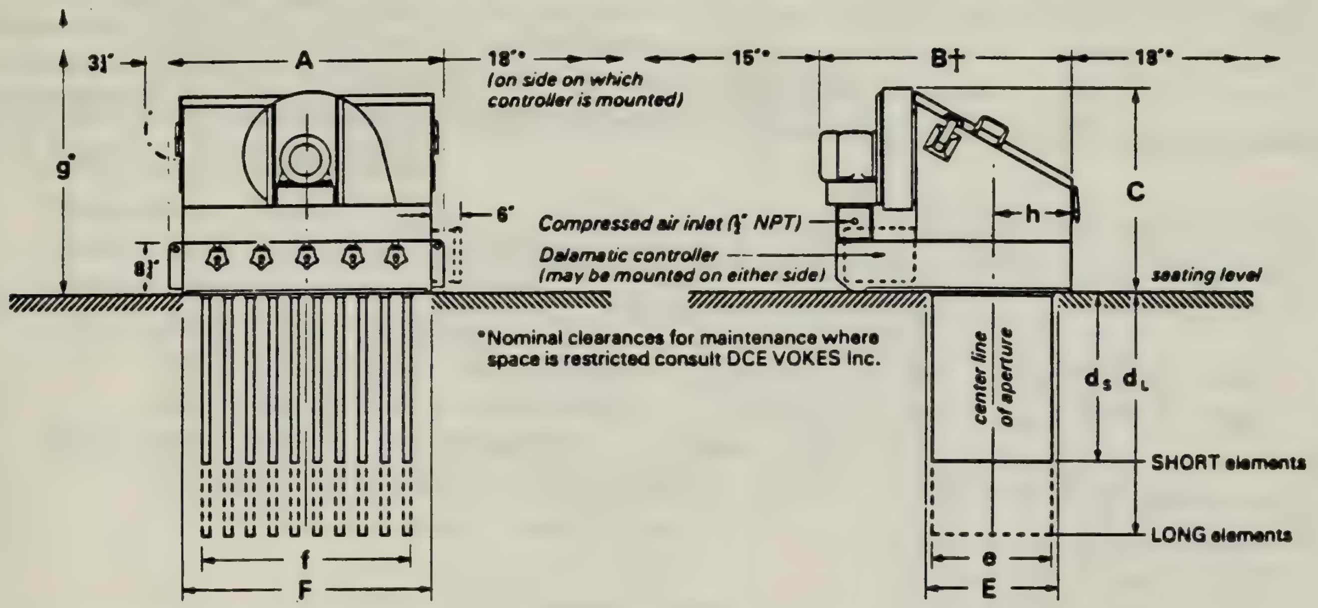
INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: DCE VOKES ③ MODEL INTEGRAL W/ FILTER UNIT ③
SIZE: – SPEED 3600 RPM
CAPACITY: 2000 ACFM STATIC PRESSURE 5" WG. ±
TYPE: CENTRIFUGAL
MOTOR SIZE: 7.5 BHP

NOTES: ① PLANT PRODUCTION: 117,275 BPD SHALE OIL; 61,730 TPD ROCK
② FIGURE WITH ASTERISK (*) APPLIES TO AN ALTERNATE OF USING CHEMICAL SPRAY AT 85% EFFICIENCY
③ OR EQUIVALENT

DCE VOKES

Dalamatic Insertable Filter Series DLM-V, type F

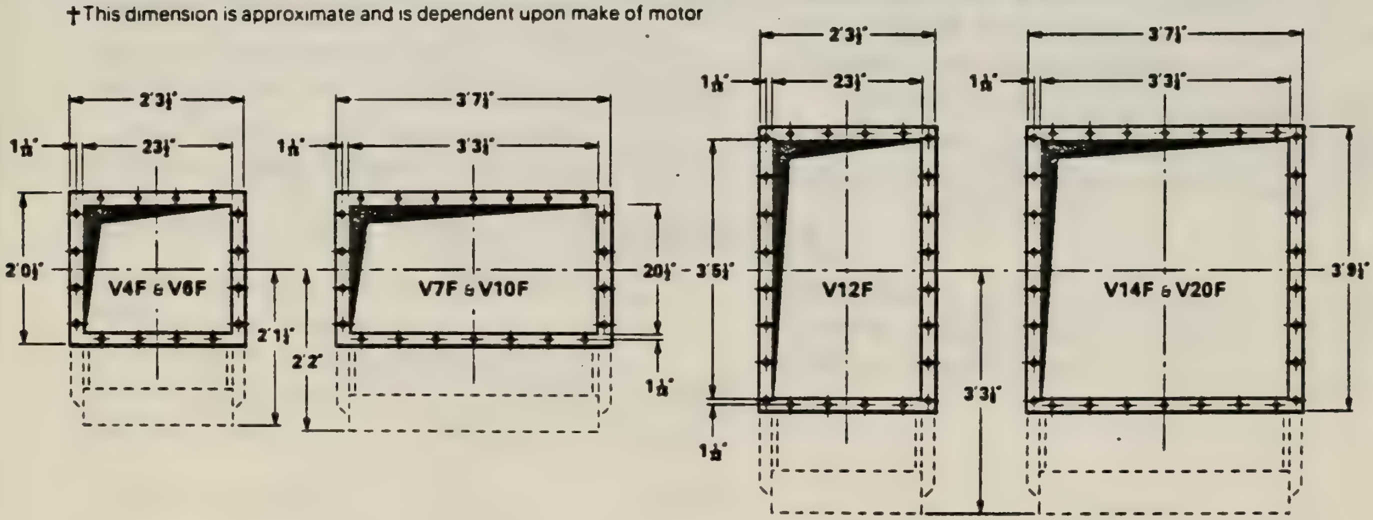


FRONT ELEVATION SIDE ELEVATION

Size DLM-V7F illustrated, broken lines representing DLM-V10F

MODEL	Fan Motor h.p.	DIMENSIONS (Tolerance ±[illegible]" on main dimensions) A	B†	C	d_S	d_L	E	e	F	f	g*	h	Approx. net. weight
DLM-V4F	1	2'3[illegible]"	3'1[illegible]"	2'6[illegible]"	2'3[illegible]"	–	20[illegible]"	19"	23[illegible]"	18[illegible]"	3'7"	12[illegible]"	320 lb
DLM-V6F	1	2'3[illegible]"	3'1[illegible]"	2'6[illegible]"	–	3'3[illegible]"	20[illegible]"	19"	23[illegible]"	18[illegible]"	4'11"	12[illegible]"	350 lb
DLM-V7F	2	3'7[illegible]"	3'2[illegible]"	2'9[illegible]"	2'3[illegible]"	–	20[illegible]"	19"	3'3[illegible]"	2'8[illegible]"	3'7"	12[illegible]"	620 lb
DLM-V10F	2	3'7[illegible]"	3'2[illegible]"	2'9[illegible]"	–	3'3[illegible]"	20[illegible]"	19'	3'3[illegible]"	2'8[illegible]"	4'11"	12[illegible]"	670 lb
DLM-V12F	4	2'3[illegible]"	5'1[illegible]"	211"	–	3'3[illegible]"	3'5[illegible]"	3'3[illegible]"	23[illegible]"	18[illegible]"	4'11"	22[illegible]"	660 lb
DLM-V14F	4	3'7[illegible]"	5'1[illegible]"	2'11"	2'3[illegible]"	–	3'5[illegible]"	3'3[illegible]"	3'3[illegible]"	2'8[illegible]"	3'7"	22[illegible]"	850 lb
DLMV20F	5[illegible]	3'7[illegible]"	5'1[illegible]"	3'1"	–	3'3[illegible]"	3'5[illegible]"	3'3[illegible]"	3'3[illegible]"	2'8[illegible]"	4'11"	22[illegible]"	960 lb

†This dimension is approximate and is dependent upon make of motor



Aperture and mounting details

The Dalamatic Filter is designed to metric standards

All bolt holes are 11mm dia. ([illegible]") for 10mm ([illegible]") bolts with hole centres at 150mm (5[illegible]") pitch, and are symmetrical about center lines as shown above

SHEET 18

REV. 3 - 3-18-81 REV. 2 - 1-19-81 REV. 1 - 9-15-80

G-414
REV.11/62

Dravo PITTSBURGH, PENNSYLVANIA	ENGINEERING COMPUTATIONS	EST NO. ___ CONT NO. M 7545 DIVISION DENVER
COMPANY OCCIDENTAL OIL SHALE, INC. LOCATION RIO BLANCO COUNTY, COLORADO DESCRIPTION AIR POLLUTION EMISSION SOURCE		DATE JUNE 2, 1980 DR E.K. CH LPC REF 6/20

1.0 AIR POLLUTION DATA

EMISSION POINT: 19 (Ref.: Dravo Drwg. No EM-101 Rev. D)
EMISSION SOURCE: Secondary & Tertiary Crushing & Screening Area
PROPOSED CONTROL SYSTEM: Baghouse EFF. 99.5 %
POLLUTANT: Raw Shale, Point Source Dust
UNCONTROLLED EMISSION: 108.08 TPD 37,828.0 TPY
CONTROLLED EMISSION: 0.54 TPD 189.0 TPY
EMISSION POINT GEOMETRY: TYPE Point
COORD. N181912.50; E1237250.00 ELEV. 7000'-0 A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	142,000	ACFM	109,908.	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	9006.7	LB/HR	9.56	GR/SCF
OUTLET DUST CONCENTRATION:	45.03	LB/HR	0.0478	GR/SCF
PER CENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

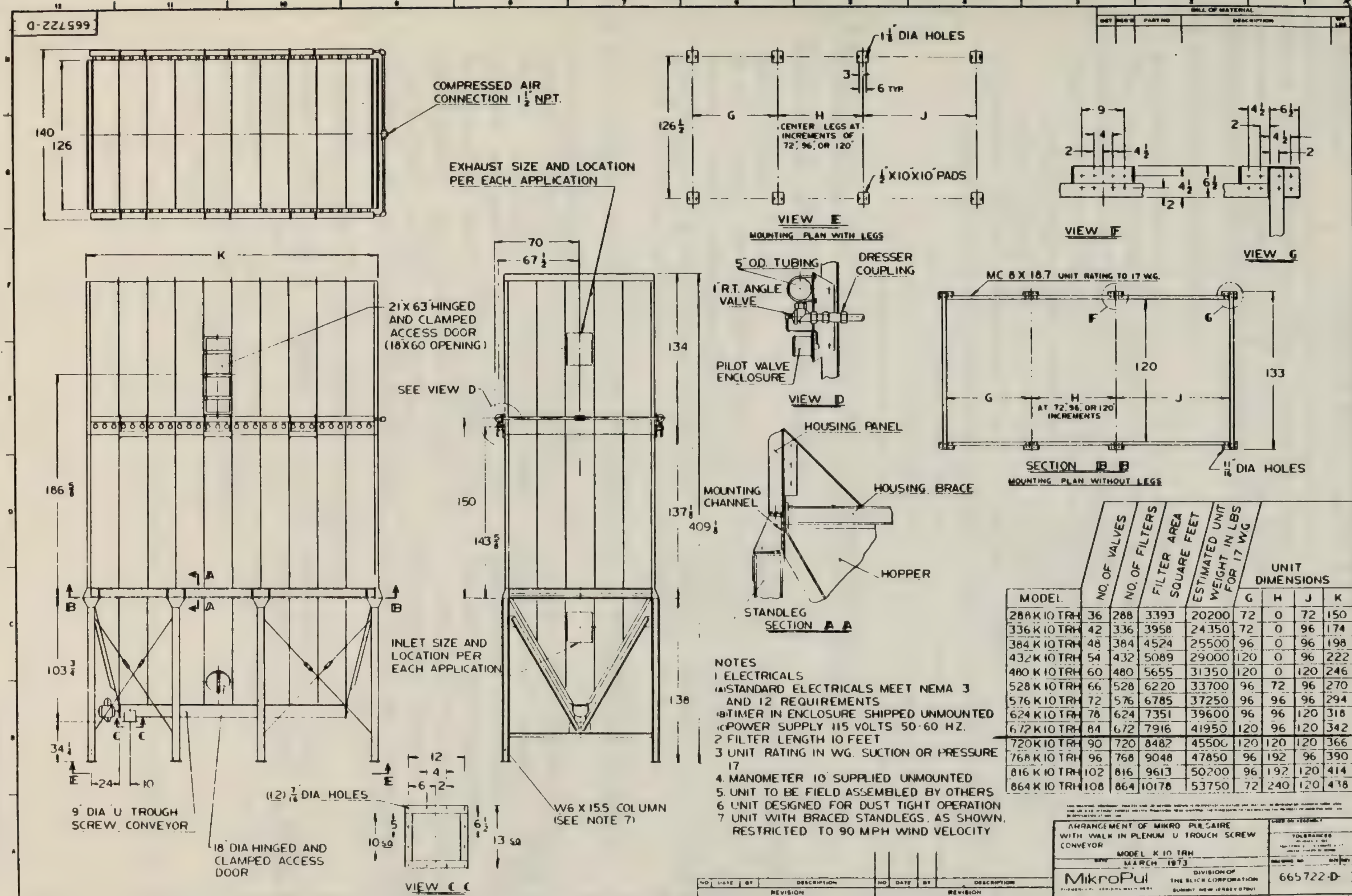
DUST COLLECTION FILTER UNIT

MAKE: MikroPul (U.S. Filter) ② MODEL: (3) 672 K10-TRH ②
SIZE: 23,059 FT² FILTER AREA NUMBER OF BAGS: 1953
LENGTH OF BAGS: 10 FT. DIAMETER OF BAGS: 4.5 IN.
AIR TO CLOTH RATIO: 4.8:1 SCFM/ft² DESIGN TEMPERATURE OF CLOTH: (Polyester) 275 °F
METHOD OF BAG CLEAN: Reverse pulse jet type (100 psig air) PRESSURE DROP: 3½ to 4 "W.G.
OVERALL COLLECTION EFFICIENCY: 99.5% FREQUENCY OF CLEANING: As req'd. (timer control)

INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: BUFFALO FORGE MODEL L-39 ②
SIZE: 1200 SPEED 1180 RPM (Direct Drive)
CAPACITY: 142,000 ACFM STATIC PRESSURE 12" W.G.
TYPE: Centrifugal w/ BKWD CURVED
MOTOR SIZE: 400 BHP.

NOTES: ① PLANT Production: 117,275 BPD shale oil; 61,730 TPD rock.
② or Equivalent.



NOTES
1 ELECTRICALS
(A) STANDARD ELECTRICALS MEET NEMA 3 AND 12 REQUIREMENTS
(B) TIMER IN ENCLOSURE SHIPPED UNMOUNTED
(C) POWER SUPPLY 115 VOLTS 50-60 HZ.
2 FILTER LENGTH 10 FEET
3 UNIT RATING IN WG. SUCTION OR PRESSURE 17
4. MANOMETER 10" SUPPLIED UNMOUNTED
5. UNIT TO BE FIELD ASSEMBLED BY OTHERS
6 UNIT DESIGNED FOR DUST TIGHT OPERATION
7 UNIT WITH BRACED STANDLEGS, AS SHOWN, RESTRICTED TO 90 MPH WIND VELOCITY

MODEL	NO. OF VALVES	NO. OF FILTERS	FILTER AREA SQUARE FEET	ESTIMATED UNIT WEIGHT IN LBS FOR 17 WG	UNIT DIMENSIONS G	H	J	K
288 K 10 TRH	36	288	3393	20200	72	0	72	150
336 K 10 TRH	42	336	3958	24350	72	0	96	174
384 K 10 TRH	48	384	4524	25500	96	0	96	198
432 K 10 TRH	54	432	5089	29000	120	0	96	222
480 K 10 TRH	60	480	5655	31350	120	0	120	246
528 K 10 TRH	66	528	6220	33700	96	72	96	270
576 K 10 TRH	72	576	6785	37250	96	96	96	294
624 K 10 TRH	78	624	7351	39600	96	96	120	318
672 K 10 TRH	84	672	7916	41950	120	96	120	342
720 K 10 TRH	90	720	8482	45500	120	120	120	366
768 K 10 TRH	96	768	9048	47850	96	192	96	390
816 K 10 TRH	102	816	9613	50200	96	192	120	414
864 K 10 TRH	108	864	10178	53750	72	240	120	438

ARRANGEMENT OF MIKRO PULSAIRE WITH WALK IN PLENUM U TROUGH SCREW CONVEYOR
MODEL K 10 TRH
MARCH 1973
MikroPul DIVISION OF THE SLICK CORPORATION
665722-D

CO.
DENVER, COLORADO 80203.

SHEET 20

REV. 2. 1-19-81 REV. 1- 9-15-80

G-414
REV. 11/62

Dravo
PITTSBURGH, PENNSYLVANIA

ENGINEERING COMPUTATIONS

EST NO.
CONT NO. M 7545
DIVISION DENVER

COMPANY OCCIDENTAL OIL SHALE, INC.
LOCATION RIO BLANCO COUNTY, COLORADO
DESCRIPTION AIR POLLUTION EMISSION SOURCE

DATE JUNE 2, 1980
DR E.K. CH LPG
REF 6/20

1.0 AIR POLLUTION DATA

EMISSION POINT: 23 (Ref.: Dravo Drwg. No EM-101 Rev. D)
EMISSION SOURCE: Conveyor Transfer Points @ Transfer Tower Area
PROPOSED CONTROL SYSTEM: Baghouse EFF. 99.0 %
POLLUTANT: Raw Shale, Point Source Dust
UNCONTROLLED EMISSION: 12.18 TPD 4262.0 TPY
CONTROLLED EMISSION: 0.061 TPD 21.35 TPY
EMISSION POINT GEOMETRY: TYPE Point
COORD. N182 193.75; E1 237 381.25 ELEV. 6980'.0 A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	16,000	ACFM	12,402	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	1,015	LB/HR	9.6	GR/SCF
OUTLET DUST CONCENTRATION:	5.075	LB/HR	0.048	GR/SCF
PER CENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT

MAKE: Mikro Pul (U.S. Filter) ②
SIZE: 2696 FT² FILTER AREA
LENGTH OF BAGS: 10.0 FT.
AIR TO CLOTH RATIO: 4.6:1 SCFM/ft²
METHOD OF BAG CLEAN: Reverse pulse jet type (100 psig air)
OVERALL COLLECTION EFFICIENCY: 99.5%

MODEL: (1)-288 K10-TRH ②
NUMBER OF BAGS: 288
DIAMETER OF BAGS: 4.5 IN.
DESIGN TEMPERATURE OF CLOTH: (polyester) 275 °F
PRESSURE DROP: 3½ to 4 "W.G.
FREQUENCY OF CLEANING: As req'd. (timer Controlled)

INDUCED DRAFT FAN, DUST COLLECTOR

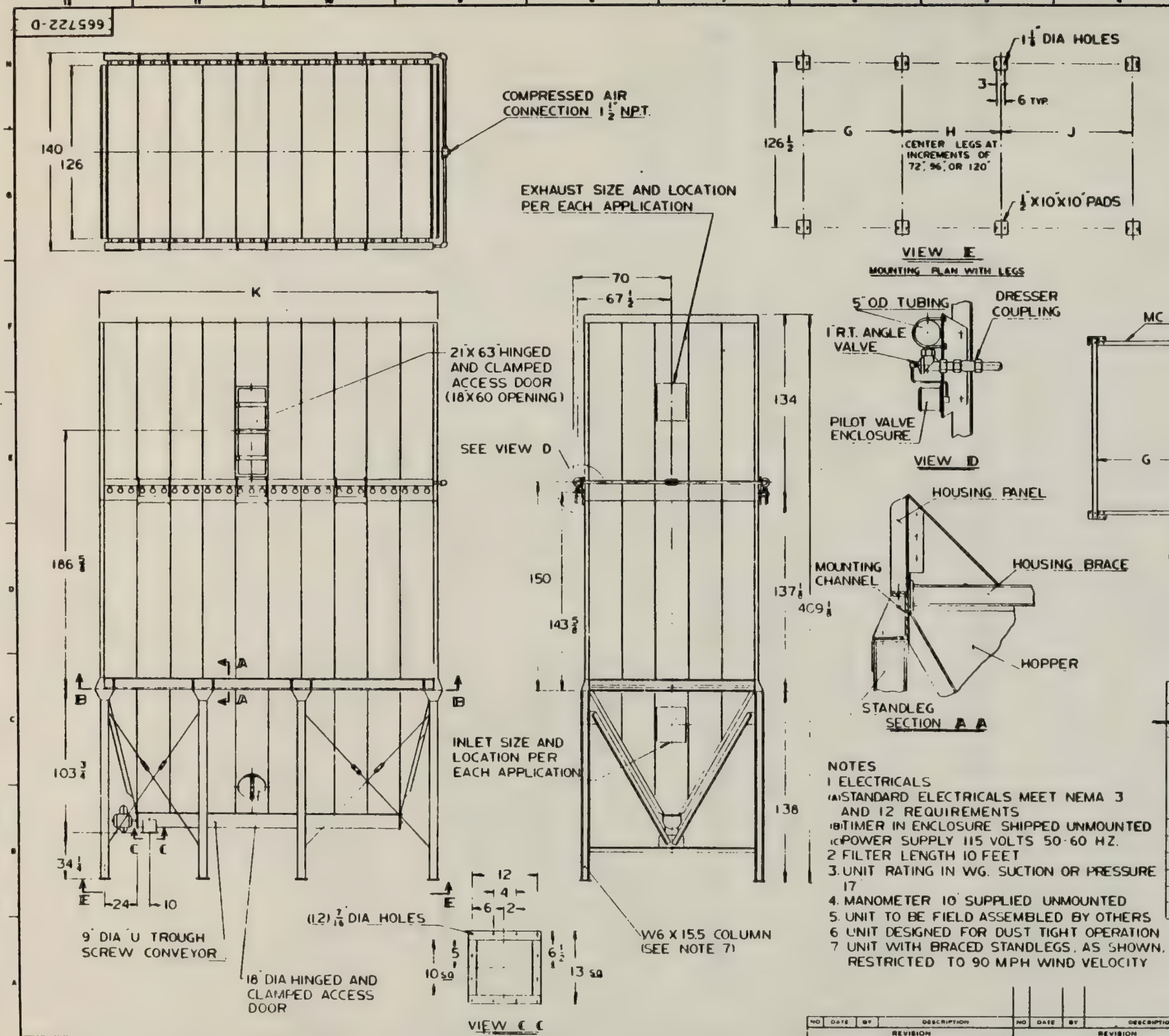
MAKE: BUFFALO FORGE ②
SIZE: 60
CAPACITY: 16,000 ACFM
TYPE: Centrifugal w/ RADIAL BLADES
MOTOR SIZE: 100 BHP

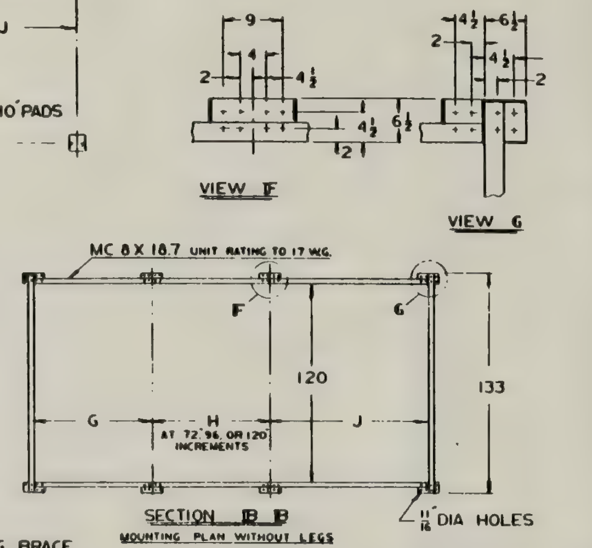
MODEL MW ②
SPEED 1134 (APPROX.)
STATIC PRESSURE 10" W.G.

NOTES: ① PLANT Production: 117,275 BPD Shale oil: 61,730 TPD rock.
② or Equivalent.

SHEET NO. 21

665722-D





NOTES
1 ELECTRICALS
(A) STANDARD ELECTRICALS MEET NEMA 3 AND 12 REQUIREMENTS
(B) TIMER IN ENCLOSURE SHIPPED UNMOUNTED
(C) POWER SUPPLY 115 VOLTS 50-60 HZ.
2 FILTER LENGTH 10 FEET
3. UNIT RATING IN WG. SUCTION OR PRESSURE 17
4. MANOMETER 10" SUPPLIED UNMOUNTED
5. UNIT TO BE FIELD ASSEMBLED BY OTHERS
6 UNIT DESIGNED FOR DUST TIGHT OPERATION
7 UNIT WITH BRACED STANDLEGS, AS SHOWN, RESTRICTED TO 90 MPH WIND VELOCITY

MODEL	NO. OF VALVES	NO. OF FILTERS	FILTER AREA SQUARE FEET	ESTIMATED UNIT WEIGHT IN LBS FOR 17 WG	UNIT DIMENSIONS G	H	J	K
288 K 10 TRH	36	288	3393	20200	72	0	72	150
336 K 10 TRH	42	336	3958	24350	72	0	96	174
384 K 10 TRH	48	384	4524	25500	96	0	96	198
432 K 10 TRH	54	432	5089	29000	120	0	96	222
480 K 10 TRH	60	480	5655	31350	120	0	120	246
528 K 10 TRH	66	528	6220	33700	96	72	96	270
576 K 10 TRH	72	576	6785	37250	96	96	96	294
624 K 10 TRH	78	624	7351	39600	96	96	120	318
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816 K 10 TRH	102	816	9613	50700	96	192	120	414
864 K 10 TRH	108	864	10178	53750	72	240	120	438

ARRANGEMENT OF MIKRO PULSAIRE WITH WALK IN PLENUM U TROUGH SCREW CONVEYOR
MODEL K 10 TRH
MARCH 1973
MikroPul
DIVISION OF THE SLICK CORPORATION
665722-D

NORTHWESTERN CO.
DENVER, COLORADO 80203

SHEET 22

G-414
REV.11/62

REV. 1- 9-15-80

Dravo
PITTSBURGH, PENNSYLVANIA

ENGINEERING COMPUTATIONS

EST NO. ______
CONT NO. M 7545
DIVISION DENVER

COMPANY OCCIDENTAL OIL SHALE, INC.
LOCATION RIO BLANCO COUNTY, COLORADO
DESCRIPTION AIR POLLUTION EMISSION SOURCE

DATE JUNE 2, 1980
DR E.K. CH LPG
REF 6/20

1.0 AIR POLLUTION DATA

EMISSION POINT: 26 (Ref.: Dravo Drwg No EM-101 Rev. D)
EMISSION SOURCE: 30000 Ton Fine Storage Silo Load-in
PROPOSED CONTROL SYSTEM: Bin Filter EFF. 99.0 %
POLLUTANT: Raw Shale Point Source Dust
UNCONTROLLED EMISSION: 0.91 TPD 318.5 TPY
CONTROLLED EMISSION: 0.009 TPD 3.15 TPY
EMISSION POINT GEOMETRY: TYPE Point
COORD. N181125.00; E1236926.56 ELEV. 7060'-0 A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	1200	ACFM	927	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	75.8	LB/HR	9.5	GR/SCF
OUTLET DUST CONCENTRATION:	0.76	LB/HR	0.095	GR/SCF
PERCENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT

MAKE: Mikro Pul (U.S. Filter) ②
MODEL: UFV-200 ②
SIZE: 200 FT² FILTER AREA
NUMBER OF BAGS: 60
LENGTH OF BAGS: 3.54 FT.
DIAMETER OF BAGS: 4 1/8 IN.
AIR TO CLOTH RATIO: 4.64:1 SCFM/ft²
DESIGN TEMPERATURE OF CLOTH: (polyester) 275 °F
METHOD OF BAG CLEAN: Mechanical Shaker
PRESSURE DROP: 3 ± "W.G.
OVERALL COLLECTION EFFICIENCY: 99 %
FREQUENCY OF CLEANING: As req'd (timer controlled)

INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: New York Blower ②
MODEL Compact G1 ②
SIZE: 104
SPEED 2924 RPM (approx.)
CAPACITY: 1200 ACFM
STATIC PRESSURE 3" W.G. ±
TYPE: Centrifugal
MOTOR SIZE: 2.0 BHP

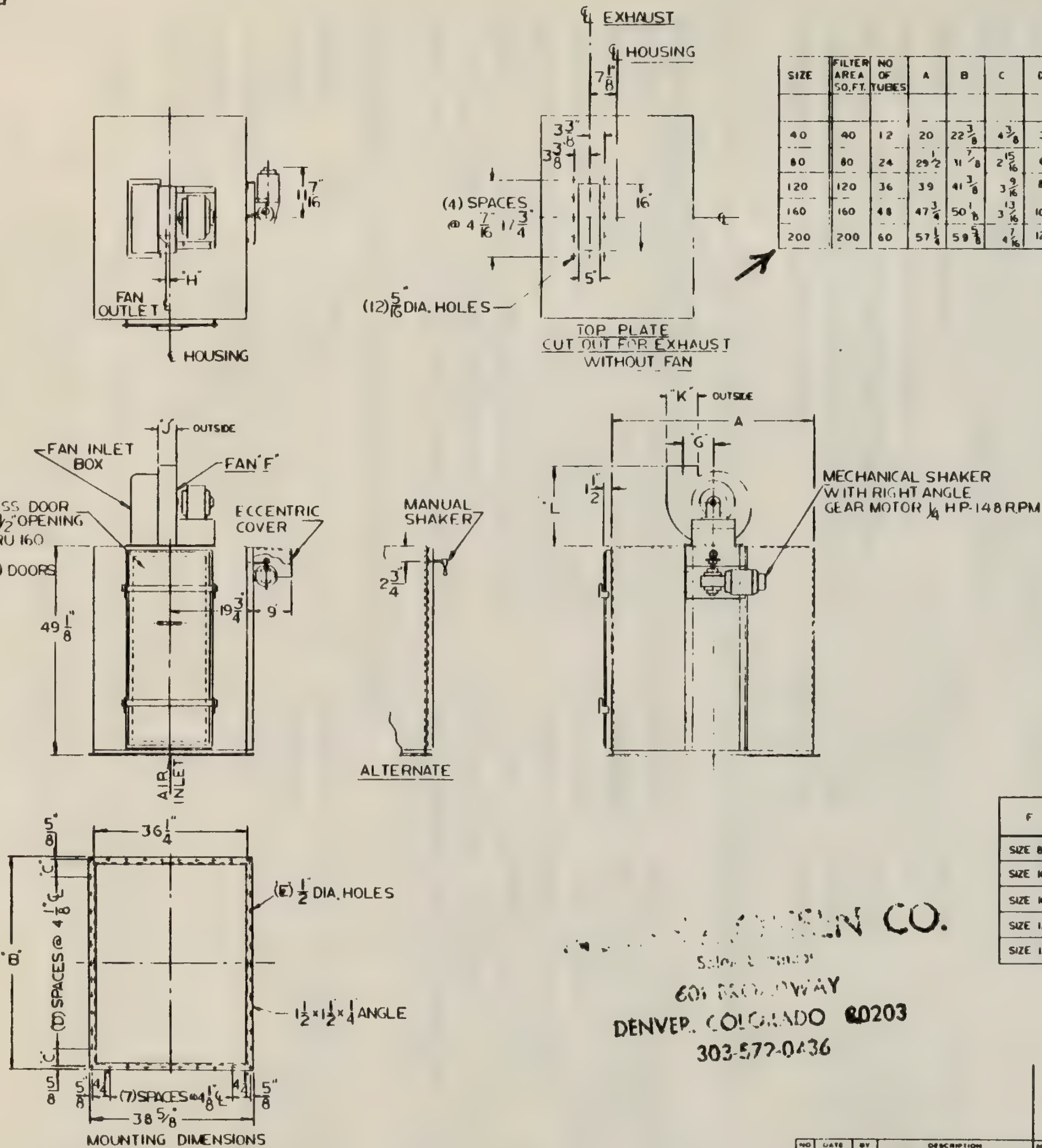
Fan is furnished integral with each filter unit.

NOTES: ① PLANT Production: 117,275 BPD shale oil; 61,730 TPD rock.
② Or Equivalent

SHEET NO. 23

DET	REQ'D	PART NO	DESCRIPTION	WT LBS

BILL OF MATERIAL



SIZE	FILTER AREA SQ.FT.	NO OF TUBES	A	B	C	D	E	APPROX. CASING WT	SHAKER MOTOR WT.
40	40	12	20	22 3/8	4 3/8	3	28	255	35
80	80	24	29 1/2	11 7/8	2 15/16	6	34	320	35
120	120	36	39	41 3/8	3 9/16	8	38	370	35
160	160	48	47 3/4	50 1/8	3 13/16	10	42	415	35
200	200	60	57 1/4	59 5/8	4 7/16	12	46	465	35

SPECIFICATIONS

CONSTRUCTION-MATERIAL TO BE CARBON STEEL NO. 14 GA. MIN.

FILTER CLOTH

- ☐ COTTON SATEEN
- ☐ OTHER

PAINT

- ☐ 1-COAT OF RED IRON OXIDE ZINC CROMATE PRIMER INSIDE & OUTSIDE
- ☐ OTHER

FILTER UNIT- REQUIREMENTS

UNITS ARE AVAILABLE WITH MANUAL, OR MECHANICAL SHAKER, ALSO WITH, OR, WITHOUT FAN.

RECOMMENDED RATIOS FOR AIRFLOW 3:1 TO 4:1

MOTORS

ALL MOTORS 3 PH 60 HZ $\frac{230}{460}$ TEFC OR EXPLOSION PROOF

F	G	H	J	K	L	APPROX. WT. FAN W/O MOTOR	FAN INLET BOX WT
SIZE 83	4 9/16	1	3 5/8	4 5/8	16 1/2	40	25
SIZE 103	5 11/16	1	3 5/8	5 5/8	18	45	25
SIZE 104	5 11/16	ON ℄	5 5/8	5 5/8	18	50	25
SIZE 123	7 3/4	1	3 5/8	7	19	60	25
SIZE 124	7 3/4	ON ℄	5 5/8	7	19	65	25

CO.
601 BROADWAY
DENVER, COLORADO 80203
303-572-0436

WORK SAFELY TODAY

NO	DATE	BY	DESCRIPTION

REVISION

NO	DATE	BY	DESCRIPTION

REVISION

UNIFILTER-BIN VENT TYPE
WITH TOP MOUNTED FAN
MODEL UFV

JUNE 1975

MikroPul DIVISION — UNITED STATES FILTER CORPORATION, SUMMIT NEW JERSEY

666673 D

SHEET 24

REV. 3 - 3-18-81, REV. 2 - 1-19-81 REV. 1 - 9-15-80

G-414 REV. 11/62

Dravo PITTSBURGH, PENNSYLVANIA

ENGINEERING COMPUTATIONS

EST NO. ____
CONT NO. M 7545
DIVISION DENVER

COMPANY OCCIDENTAL OIL SHALE, INC.
LOCATION RIO BLANCO COUNTY, COLORADO
DESCRIPTION AIR POLLUTION EMISSION SOURCE

DATE JUNE 2, 1980
DR E.K. CH LPG 6/20
REF ____

1.0 AIR POLLUTION DATA

EMISSION POINT: 27 (Ref.: Dravo Drwg No. EM-101 Rev. D)
EMISSION SOURCE: 30000 Ton Fine Storage Silo - Load-out
PROPOSED CONTROL SYSTEM: Insertable Baghouse EFF. 99.5 %
POLLUTANT: Raw Shale, Point Source Dust
UNCONTROLLED EMISSION: 0.108 TPD 37.8 TPY
CONTROLLED EMISSION: 0.0005/0.0162* TPD 0.175/5.67* TPY ②
EMISSION POINT GEOMETRY: TYPE Point
COORD. N181 162.50; E1 237 062.50 ELEV. 6908'-0 A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	2000	ACFM	1553	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	9.0	LB/HR	0.68	GR/SCF
OUTLET DUST CONCENTRATION:	0.045	LB/HR	0.0034	GR/SCF
PER CENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT

MAKE: DCE Vokes Dalamatic Insertable Filter ③
MODEL: DLM-V20 type F ③
SIZE: 210 FT² FILTER AREA
NUMBER OF BAGS: 20
LENGTH OF BAGS: 3.33 FT.
WIDTH OF BAGS: 39.5 IN.
AIR TO CLOTH RATIO: 7.39:1 SCFM/ft²
DESIGN TEMPERATURE OF CLOTH: (polyester) 275 °F
METHOD OF BAG CLEAN: Reverse pulse jet type (100 psig air)
PRESSURE DROP: 3± "W.G.
OVERALL COLLECTION EFFICIENCY: 99.5%
FREQUENCY OF CLEANING: As req'd. (Ajustable time interval: 6 to 30 sec.)

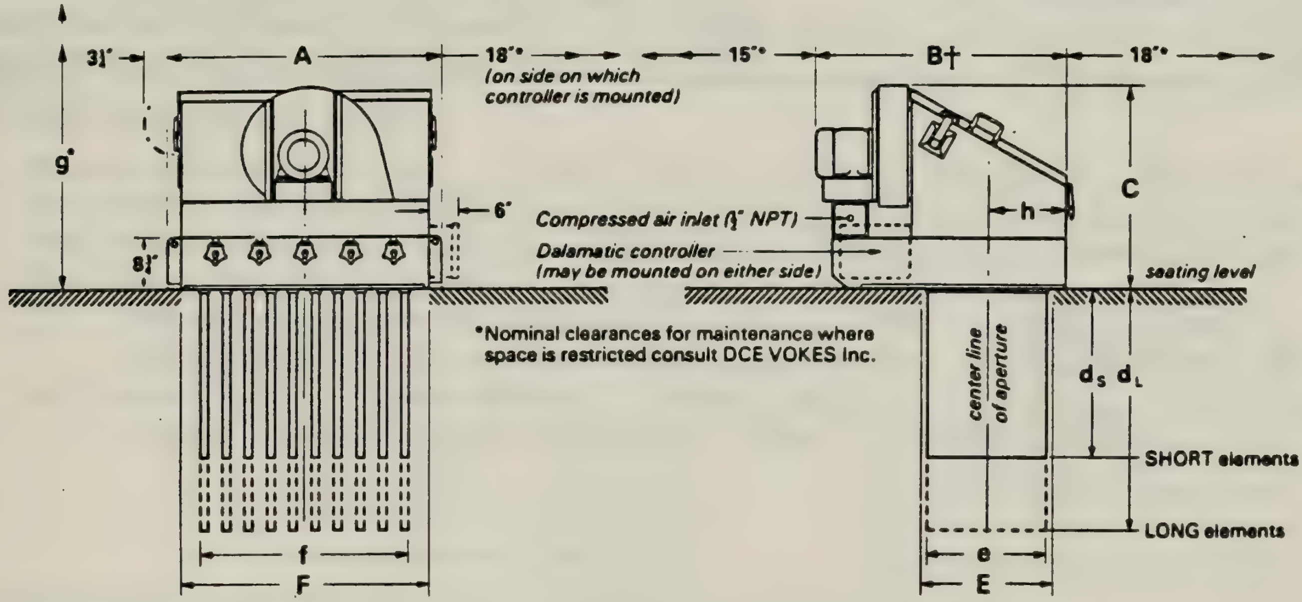
INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: DCE Vokes ③
MODEL Integral with filter unit ③
SIZE: -
SPEED 3600 RPM
CAPACITY: 2000 ACFM
STATIC PRESSURE 5" W.G. ±
TYPE: Centrifugal
MOTOR SIZE: 7.5 BHP.

NOTES: ① PLANT Production: 117,275 BPD Shale Oil; 61,730 TPD rock.
② Figure with asterisk (*) applies to an alternate of using chemical spray at 85% efficiency.
③ Or Equivalent.

SHEET NO. 25

Dalamatic Insertable Filter Series DLM-V, type F



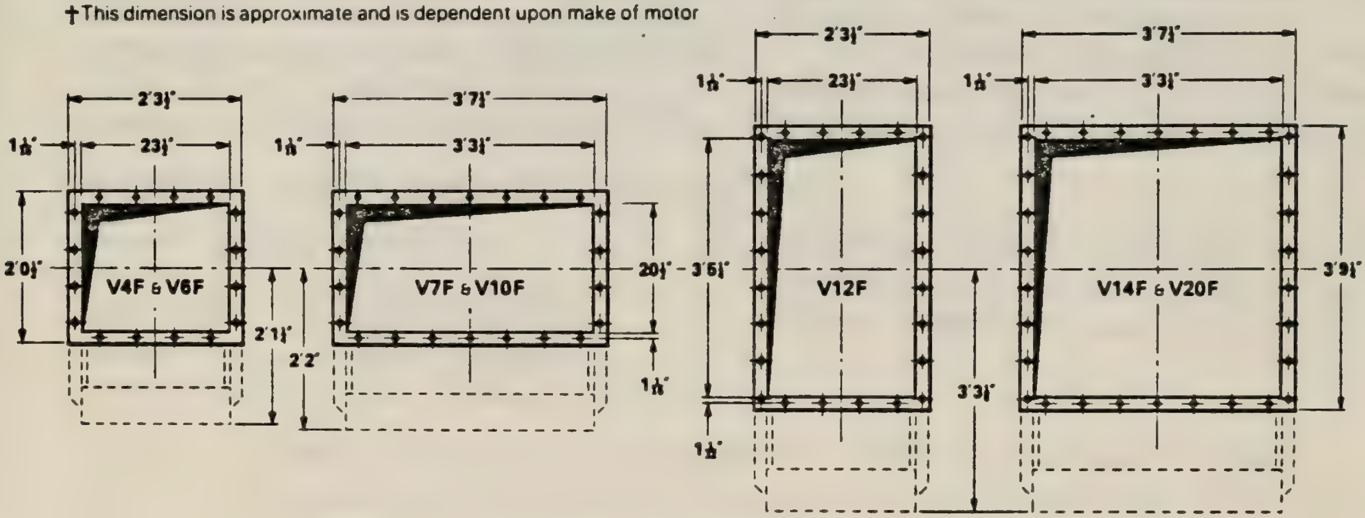
FRONT ELEVATION

SIDE ELEVATION

Size DLM-V7F illustrated, broken lines representing DLM-V10F

MODEL	Fan Motor h.p.	DIMENSIONS (Tolerance ±½" on main dimensions) A	B†	C	d_S	d_L	E	e	F	f	g*	h	Approx. net. weight
DLM-V4F	1	2'3½"	3'1½"	2'6½"	2'3½"	–	20½"	19"	23½"	18½"	3'7"	12½"	320 lb
DLM-V6F	1	2'3½"	3'1½"	2'6½"	–	3'3½"	20½"	19"	23½"	18½"	4'11"	12½"	350 lb
DLM-V7F	2	3'7½"	3'2¾"	2'9½"	2'3½"	–	20½"	19"	3'3½"	2'8½"	3'7"	12½"	520 lb
DLM-V10F	2	3'7½"	3'2¾"	2'9½"	–	3'3½"	20½"	19"	3'3½"	2'8½"	4'11"	12½"	570 lb
DLM-V12F	4	2'3½"	5'1⅞"	211"	–	3'3½"	3'5½"	3'3½"	23½"	18½"	4'11"	22½"	660 lb
DLM-V14F	4	3'7½"	5'1⅞"	2'11"	2'3½"	–	3'5½"	3'3½"	3'3½"	2'8½"	3'7"	22½"	850 lb
DLMV20F	5½	3'7½"	5'1⅞"	3'1"	–	3'3½"	3'5½"	3'3½"	3'3½"	2'8½"	4'11"	22½"	960 lb

†This dimension is approximate and is dependent upon make of motor



Aperture and mounting details

The Dalamatic Filter is designed to metric standards

All bolt holes are 11mm dia. (7/16") for 10mm (⅜") bolts with hole centres at 150mm (5⅞") pitch, and are symmetrical about center lines as shown above

SHEET 26

REV. 3 - 3-12-81 REV. 2-1-19-81 REV. 1-9-15-80

G-414
REV.11/62

Dravo
PITTSBURGH, PENNSYLVANIA

ENGINEERING COMPUTATIONS

EST NO. ____
CONT NO. M 7545
DIVISION DENVER

COMPANY OCCIDENTAL OIL SHALE, INC.
LOCATION RIO BLANCO COUNTY, COLORADO
DESCRIPTION AIR POLLUTION EMISSION SOURCE

DATE JUNE 2, 1980
DR E.K. CH LPG 6/20
REF ____

1.0 AIR POLLUTION DATA

EMISSION POINT: 28 (Ref. Dravo Drwg. No EM-101 Rev. D)
EMISSION SOURCE: 30000 Ton Fine Storage Silo, Load-out
PROPOSED CONTROL SYSTEM: Insertable Baghouse EFF. 99.5 %
POLLUTANT: Raw Shale Point Source Dust
UNCONTROLLED EMISSION: 0.108 TPD 37.8 TPY
CONTROLLED EMISSION: 0.0005/0.0162* TPD 0.175/5.67 * TPY ②
EMISSION POINT GEOMETRY: TYPE Point
COORD. N181 162.50; E1237 062.50 ELEV. 6908'-0 A.S.L.

2.0 BAGHOUSE DUST COLLECTOR INFORMATION

2.1 PROCESS DESCRIPTION DATA

GAS FLOW RATE:	2000	ACFM	1553	SCFM
GAS FLOW TEMPERATURE:	70	°F	21.1	°C
INLET DUST CONCENTRATION:	9.0	LB/HR	0.68	GR/SCF
OUTLET DUST CONCENTRATION:	0.045	LB/HR	0.0034	GR/SCF
PER CENT MOISTURE:	Negligible	% BY WT.		

2.2 EQUIPMENT DESCRIPTION AND DESIGN INFORMATION DATA

DUST COLLECTION FILTER UNIT

MAKE: DCE Vokes DALAMATIC Insertable Filter ③
MODEL: DLM. V 20 type F ③
SIZE: 210 FT² FILTER AREA
NUMBER OF BAGS: 20
LENGTH OF BAGS: 3.33 FT.
WIDTH OF BAGS: 39.5 IN.
AIR TO CLOTH RATIO: 7.39 : 1 SCFM/ft²
DESIGN TEMPERATURE OF CLOTH: (polyester) 275 °F
METHOD OF BAG CLEAN: Reverse pulse jet type (100 psig air)
PRESSURE DROP: 3± "W.G.
OVERALL COLLECTION EFFICIENCY: 99.5%
FREQUENCY OF CLEANING: As req'd.

INDUCED DRAFT FAN, DUST COLLECTOR

MAKE: DCE Vokes ③
MODEL Integral with filter unit ③
SIZE:
SPEED 3600 RPM
CAPACITY: 2000 ACFM
STATIC PRESSURE 5" W.G. ±
TYPE: Centrifugal
MOTOR SIZE: 7.5 BHP

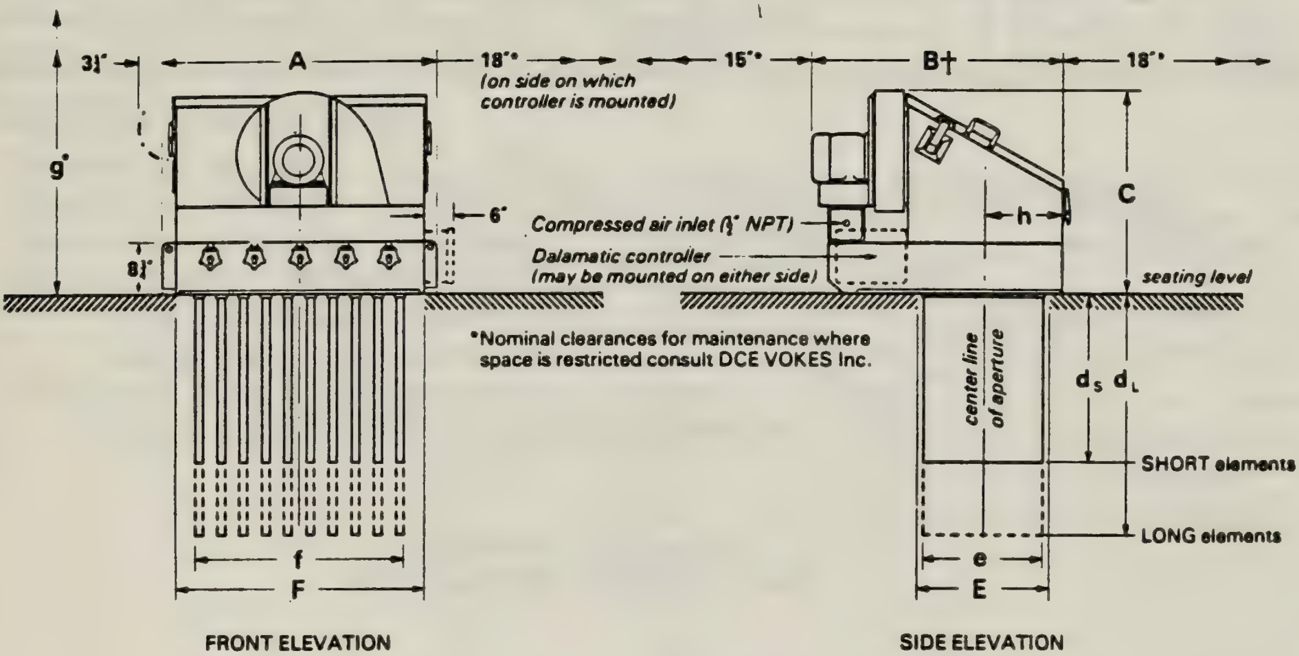
NOTES: ① PLANT Production: 117,275 BPD Shale Oil; 61,730 TPD rock
② Figure with asterisk (*) applies to an alternate of using chemical spray at 85% Efficiency.
③ or Equivalent

SHEET NO. 27

DATA SHEET 359

Dalamatic Insertable Filter Series DLM-V, type F

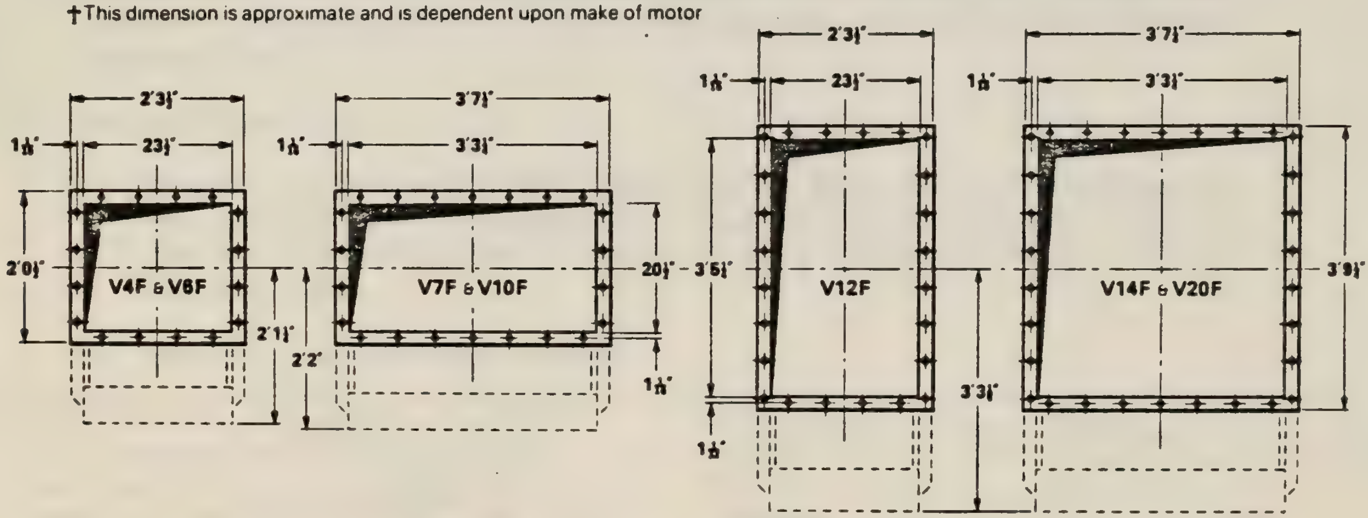
DCE VOKES



Size DLM-V7F illustrated, broken lines representing DLM-V10F

MODEL	Fan Motor h.p.	A	B†	C	d_S	d_L	E	e	F	f	g*	h	Approx. net. weight
		DIMENSIONS (Tolerance ±¼" on main dimensions)											
DLM-V4F	1	2'3½"	3'1½"	2'6½"	2'3½"	–	20½"	19"	23½"	18½"	3'7"	12½"	320 lb
DLM-V6F	1	2'3½"	3'1½"	2'6½"	–	3'3½"	20½"	19"	23½"	18½"	4'11"	12½"	350 lb
DLM-V7F	2	3'7½"	3'2¾"	2'9½"	2'3½"	–	20½"	19"	3'3½"	2'8½"	3'7"	12½"	620 lb
DLM-V10F	2	3'7½"	3'2¾"	2'9½"	–	3'3½"	20½"	19"	3'3½"	2'8½"	4'11"	12½"	670 lb
DLM-V12F	4	2'3½"	5'1¾"	211"	–	3'3½"	3'5½"	3'3½"	23½"	18½"	4'11"	22½"	660 lb
DLM-V14F	4	3'7½"	5'1¾"	2'11"	2'3½"	–	3'5½"	3'3½"	3'3½"	2'8½"	3'7"	22½"	850 lb
DLMV20F	5½	3'7½"	5'1¾"	3'1"	–	3'3½"	3'5½"	3'3½"	3'3½"	2'8½"	4'11"	22½"	960 lb

†This dimension is approximate and is dependent upon make of motor



Aperture and mounting details

The Dalamatic Filter is designed to metric standards

All bolt holes are 11mm dia. (7/16") for 10mm (⅜") bolts with hole centres at 150mm (5⅞") pitch, and are symmetrical about center lines as shown above

SHEET 28

REV. 1 - 9-15-80

PITTSBURGH PENNSYLVANIA

ENGINEERING COMPUTATIONS

EST NO. ___
CONT NO. M 7541
DIVISION DENVER

COMPANY OCCIDENTAL OIL SHALE, INC.
LOCATION RIO BLANCO COUNTY, COLORADO
DESCRIPTION AIR POLLUTION EMISSION SOURCE

DATE ___
DR DS CH LPG
REF 6/20

1.0 AIR POLLUTION DATA

EMISSION POINT: 29
EMISSION SOURCE: SPENT SHALE HANDLING & DISPOSAL AREA
PROPOSED CONTROL SYSTEM: SCRUBBER EFF. 98 %
POLLUTANT: SPENT SHALE, PT. SOURCE DUST
UNCONTROLLED EMISSION: 14.48 TPD 5068.0 TPY
CONTROLLED EMISSION: 0.29 TPD 101.5 TPY
EMISSION POINT GEOMETRY: TYPE POINT
COORD. N180,730.0 E1,238,615.0 ELEV. 7016'-0

SCRUBBER INFORMATION.
NECESSARY FOR REVIEWING PLANS

Fill in the blanks and attach the rest as specified:

1. General Description
   a. Make: DUCON
   b. Model: UW-4, MOD. IV
   c. Size: 108

2. Process Description

   Attach a written description of each process to be carried out in each unit of basic equipment. Particular attention must be given to explaining all stages in the process where the discharge of any air contaminants may take place. Draw a flow diagram and refer to it in the description.

3. Design Information
   a. Attach manufacturer's literature and/or detailed specifications on the proposed control equipment. Also include source test data or similar information for a process with a similar effluent and mass emission rate.
   b. Complete the following table:

Gas Flow Rate 32,000 acfm	Liquid Flow Rate 55 GPM
Inlet Contaminant Conc 1207 lb/hr	Outlet Contaminant Conc 24.17 lb/hr
Gas Temp. (In) 200 °F	Gas Temp. (Out) 70 °F
Operating Pressure AMBIENT psi (gage)	Pressure Drop 5.0 inches of H_2O
Diameter of Stack Exit 3.7 ft.	

SHEET NO. 29

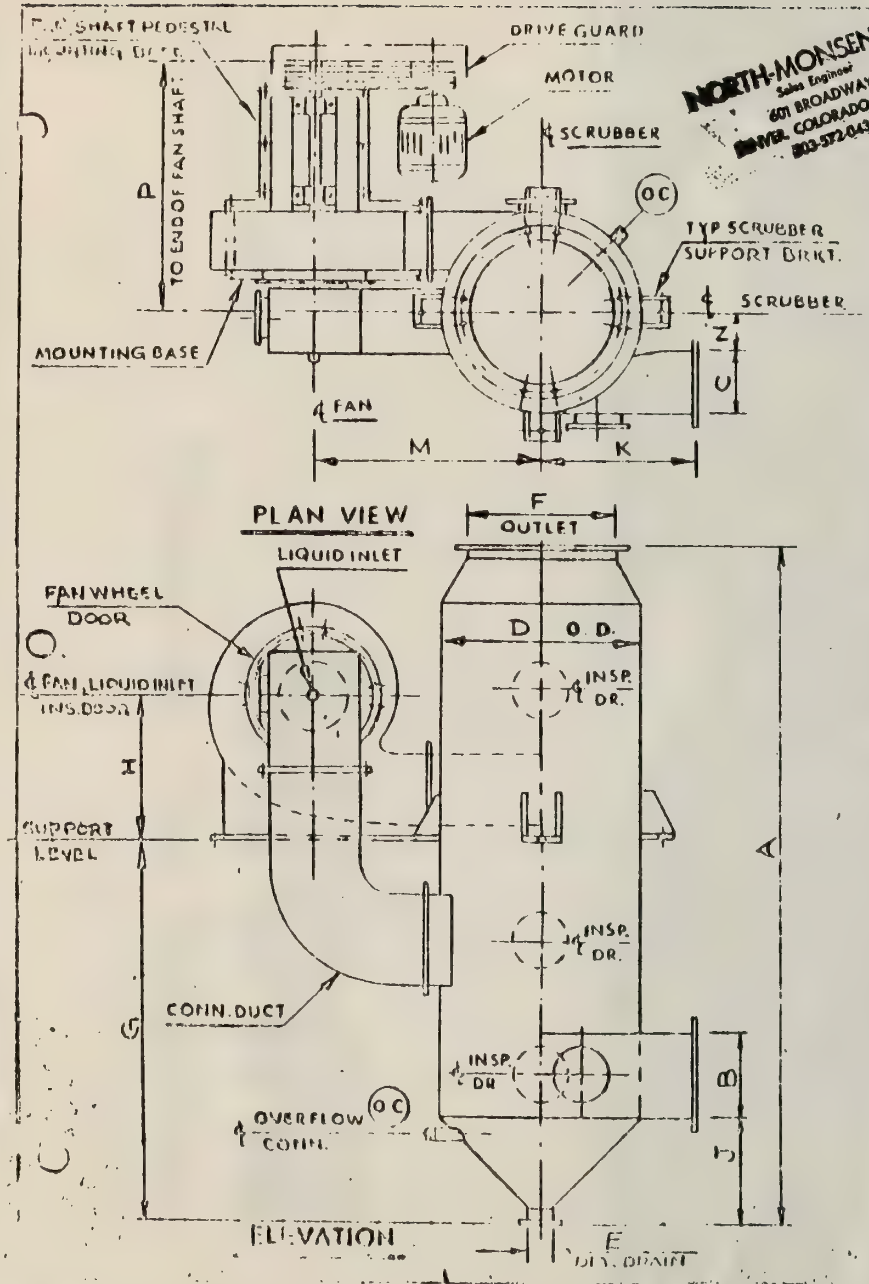
1.0 AIR POLLUTION DATA (SCRUBBER CONT'D)

c. Equipment Description

1. Type of Scrubber (e.g., Packed Tower, Venturi) DYNAMIC
2. Type of Scrubber Packing (if applicable) NONE
3. Type of Scrubbing Solution Utilized (e.g., Water, Potassium, Permanganate) WATER
4. Packed Column Height (if applicable) NONE
   Height of Transfer Unit (H_{og}) ___
   No. of Transfer Units (N_{og}) ___
   Dimensions of Venturi Throat (if applicable) ___
   Performance Tests; Inlet Particle Size Analysis; Size Efficiency
   Estimated Efficiency 99+% %

4. Description of Gas Mover

a. Make, model, size, speed, capacity (attach) INCL'D WITH SCRUBBER
b. Static pressures on each (attach). 5.0"WG
c. Motor description (attach) 100.00 hp.



DIMENSIONAL CHART FOR DUCON DYNAMIC SCRUBBER

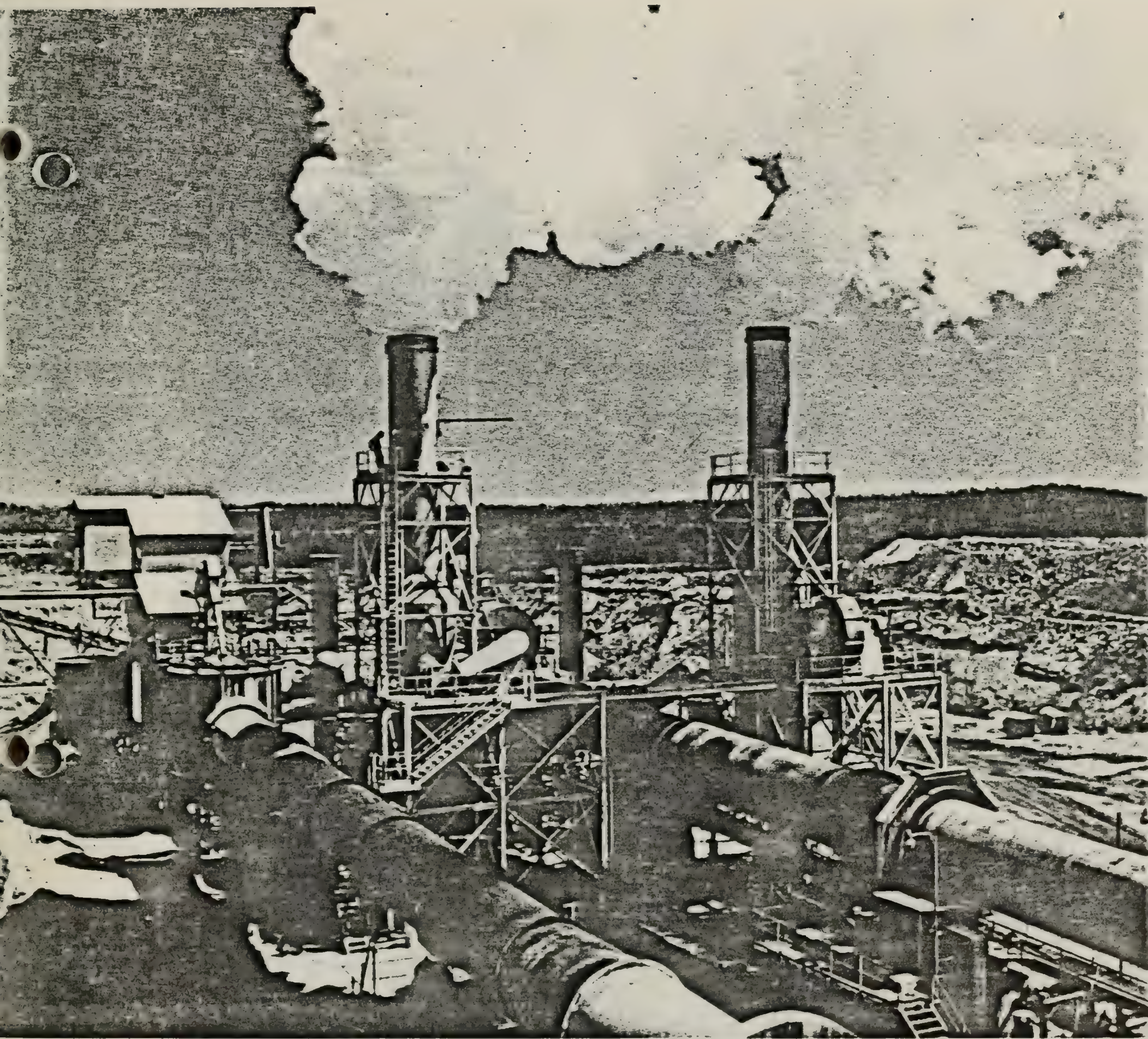
TYPE UW4 MODEL IV

SIZE D	A	B	C	E	F	G	H	J	K	M	N	P
18	6'-6"	6¾"	5¼"	4"	14⅜"	3'-2"	16½"	9"	15"	23"	3¾"	3'-0"
21	7'-1½"	8"	6"	4"	16½"	3'-5½"	16½"	10½"	18"	2'-1"	4½"	3'-2"
24	7'-7"	9	7"	4"	19¼"	3'-10"	17"	12"	20"	2'-4"	5"	3'-5
30	8'-8½"	11"	9"	6"	2'-0"	4'-5½"	17"	15"	2'-0"	2'-7"	6"	3'-11
36	10'-7½"	14"	10"	6"	2'-4¾"	5'-5½"	2'-1"	18"	2'-2"	3'-5"	8"	4'-3½
42	11'-9½"	16"	13"	8"	2'-10"	6'-2½"	2'-1"	21"	2'-6"	3'-8"	8"	4'-6½
48	13'-1½"	18"	14"	6"	3'-2½"	6'-11½"	2'-9"	2'-0"	2'-9"	4'-1"	10"	5'-0
54	14'-6"	20"	16"	8"	3'-7"	7'-6"	2'-9"	2'-3"	3'-0"	4'-4"	11"	5'-3
60	16'-2"	23"	17	8"	4'-0"	8'-5"	3'-4"	2'-6	3'-4"	5'-0	13"	6'-3
66	17'-7"	2'-1"	19"	8"	4'-4½"	9'-2"	3'-4"	2'-9	3'-6"	5'-3"	14"	6'-6
72	19'-1"	2'-4"	21"	8"	4'-9¾	10'-0"	4'-0"	3'-0"	3'-9"	5'-11"	15"	7'-3
78	20'-0"	2'-6"	23	8"	5'-2½"	10'-8"	4'-0"	3'-3"	4'-0"	6'-2"	16"	7'-6
84	21'-7"	2'-8"	2'-0"	10"	5'-7"	11'-1"	4'-6"	3'-6"	4'-4"	6'-9	18"	8'-0
90	23'-0"	2'-10"	2'-2"	10"	6'-0"	12'-2"	4'-6"	3'-9	4'-6"	7'-0"	19"	8'-3
96	24'-4"	3'-1"	2'-4	10	6'-4½"	12'-9"	5'-0	4'-0	5'-0"	7'-11"	20"	8'-10
102	25'-8"	3'-3	2'-6	10	6'-9½	13'-10	5'-0"	4'-3	5'-6"	8'-2"	21	9'-1
108	26'-7	3'-5"	2'-7	10"	7'-1¼	14'-3"	5'-0	4'-6	5'-8"	8'-5	23"	9'-4
114	28'-3"	3'-8"	2'-9"	10"	7'-7"	15'-1"	5'-8"	4'-9	5'-10"	8'-11"	2'-0"	10'-0
120	29'-11	3'-10"	2'-11"	10"	7'-11¾	16'-6"	5'-8	5'-0"	6'-2"	9'-2"	2'-1"	10'-3
126	31'-5½	4'-1"	3'-0"	10"	8'-4½"	17'-4"	6'-3"	5'-3"	6'-6"	9'-10"	2'-3"	11'-0
132	32'-0½	4'-3"	3'-2"	10"	8'-9	17'-9½	6'-3"	5'-6"	6'-10"	10'-1"	2'-4"	11'-3
138	33'-10"	4'-5	3'-4"	10"	9'-2¼	18'-5"	6'-10	5'-9"	7'-0"	10'-9"	2'-5"	11'-10
144	34'-9"	4'-7"	3'-6"	10"	9'-7¼	19'-0"	6'-10	6'-0"	7'-4"	11'-0"	2'-6"	12'-1

"CONFIDENTIAL"

THE DUCON COMPANY INC
DWG. NO. 7575-1

SHEET 31

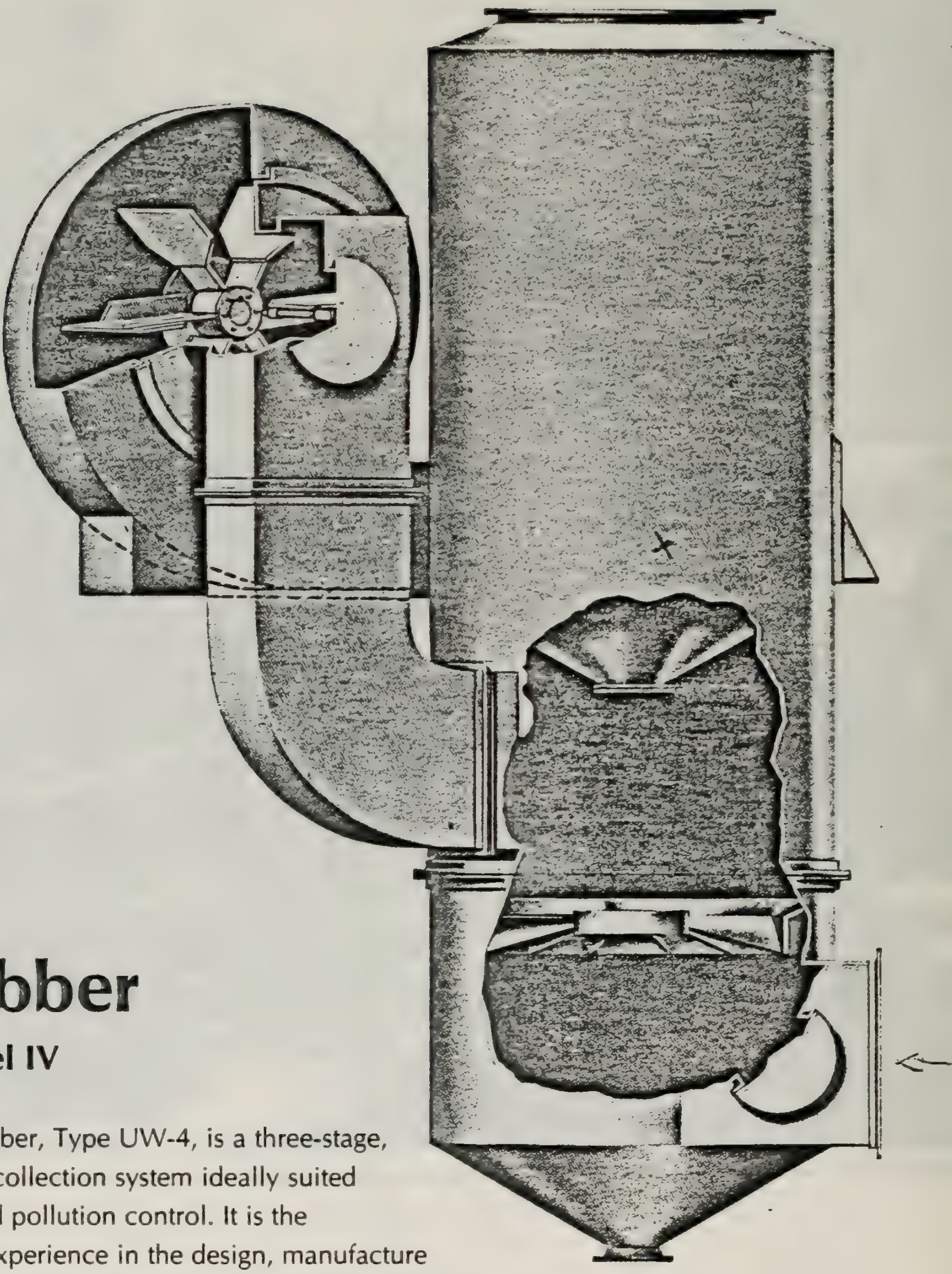


NORTH-MONSEN CO.
Sales Engineer
601 BROADWAY
DENVER. COLORADO 80203
303-572-0436

DUCON

Dynamic Gas Scrubber

Type UW-4, Model IV



Dynamic Gas Scrubber

Type UW-4, Model IV

The Dynamic Gas Scrubber, Type UW-4, is a three-stage, non-plugging, wet dust collection system ideally suited for product recovery and pollution control. It is the result of over 25 years experience in the design, manufacture and application of Dynamic Scrubbers. Hundreds of UW-4 scrubbers are in operation in the mining, fertilizer, chemical, steel, rock products, pulp and paper and allied industries. Its high collection efficiency of up to 99+% in the 1 to 2 micron range is achieved through "Dynamic" action. "Dynamic" scrubbing involves the use of a wet fan to mix gas, dust and water, in extreme turbulence, which forces dust particles into the scrubbing liquid.

Advantages

1. Continuous performance at maximum collection efficiencies.

2. Constant speed of "Dynamic Fan" assures peak performance even when gas flows are as low as 60-70% of design capacity.

3. Ability to handle upset conditions.

4. Built-in fan also acts as prime mover which eliminates need for additional exhaust fan to overcome system resistance external to scrubber. This also results in savings in installation cost.

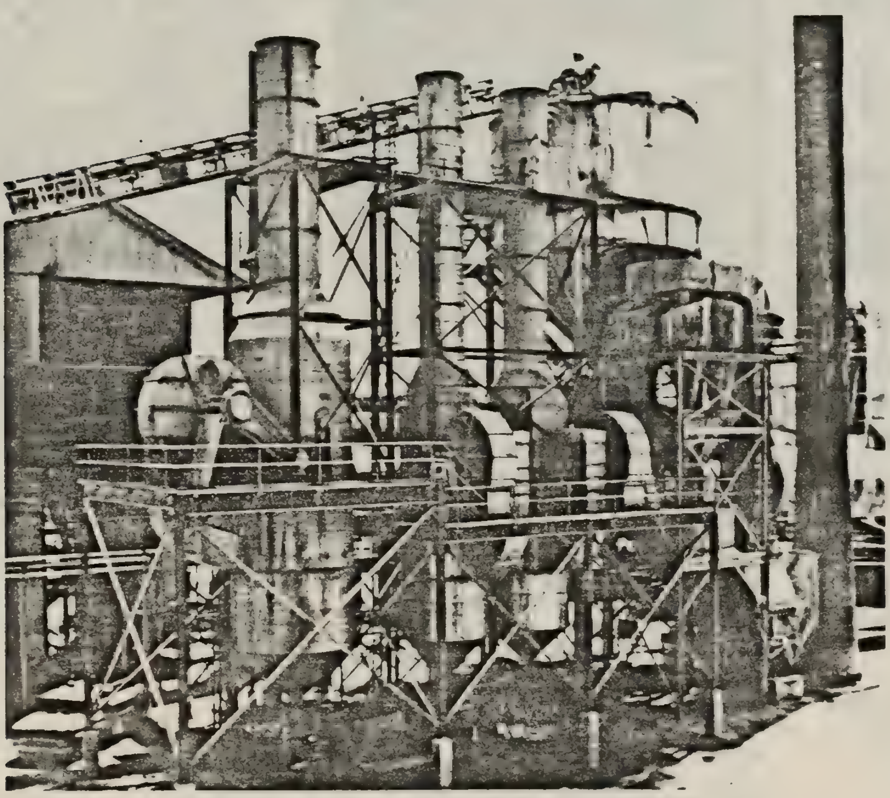
5. Thoroughly wetted fan greatly reduces normal problems of condensation, solids build-up and/or abrasion.

6. No wet/dry areas in system and no small openings to plug.

7. Minimum water usage since scrubbing liquid can be recycled.

8. Instantaneous start-up and shutdown are possible because no water level must be maintained.

9. Low maintenance.

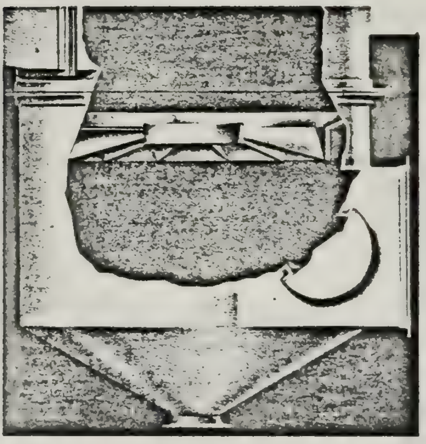


Features

The Ducon Dynamic Scrubber, Type UW-4, has proved to be the most reliable and dependable choice for all drying and calcining kiln applications, pelletizing and sintering plants and for control of all types of material handling such as conveyor transfer points, screens, bins crushers and mills. It is also used in fluid bed processing and in cooling, classifying and general dust ventilation operations.

The wide acceptance of Ducon's Dynamic UW-4 Scrubber can be attributed as much to its maintenance-free operation as to its highly efficient performance. On-line performance is maintained even under severe or adverse operating conditions. On rotary limestone kilns, lime hydrators, and lime slakers, which are recognized as being very difficult applications, this unit is used extensively because it has proved to require less maintenance than other scrubber designs.

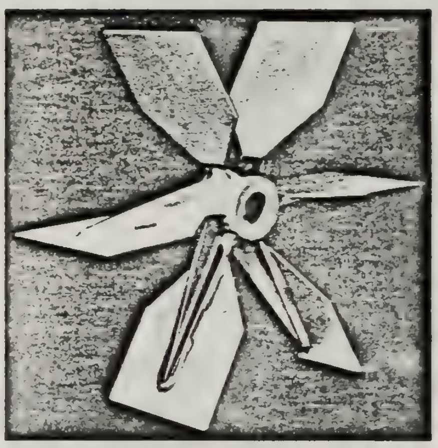
Two-Stage Pre-Cleaner



The pre-cleaner section of the Dynamic UW-4 scrubber provides several immediate advantages for the system. By eliminating up to 90% of the dust load before the fan section and causing particle growth through cooling and condensation on the remaining suspended particles, it promotes higher operating efficiencies in the two remaining stages.

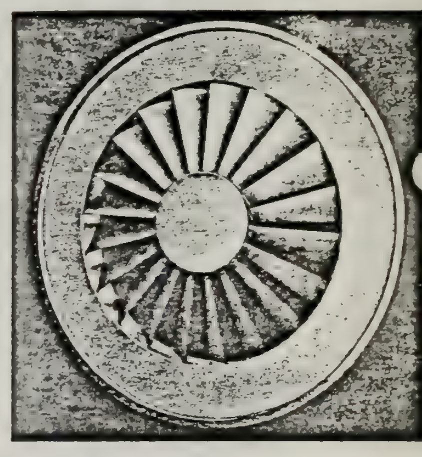
The wide open design of the pre-cleaner section assures trouble-free, non-plugging operation. Its efficiency and dependability have been proven in hundreds of difficult applications. Complete liquid flushing of the scrubbing vane in the UW-4 scrubber is another important factor in the elimination of build-up and plugging problems.

Fan Impeller

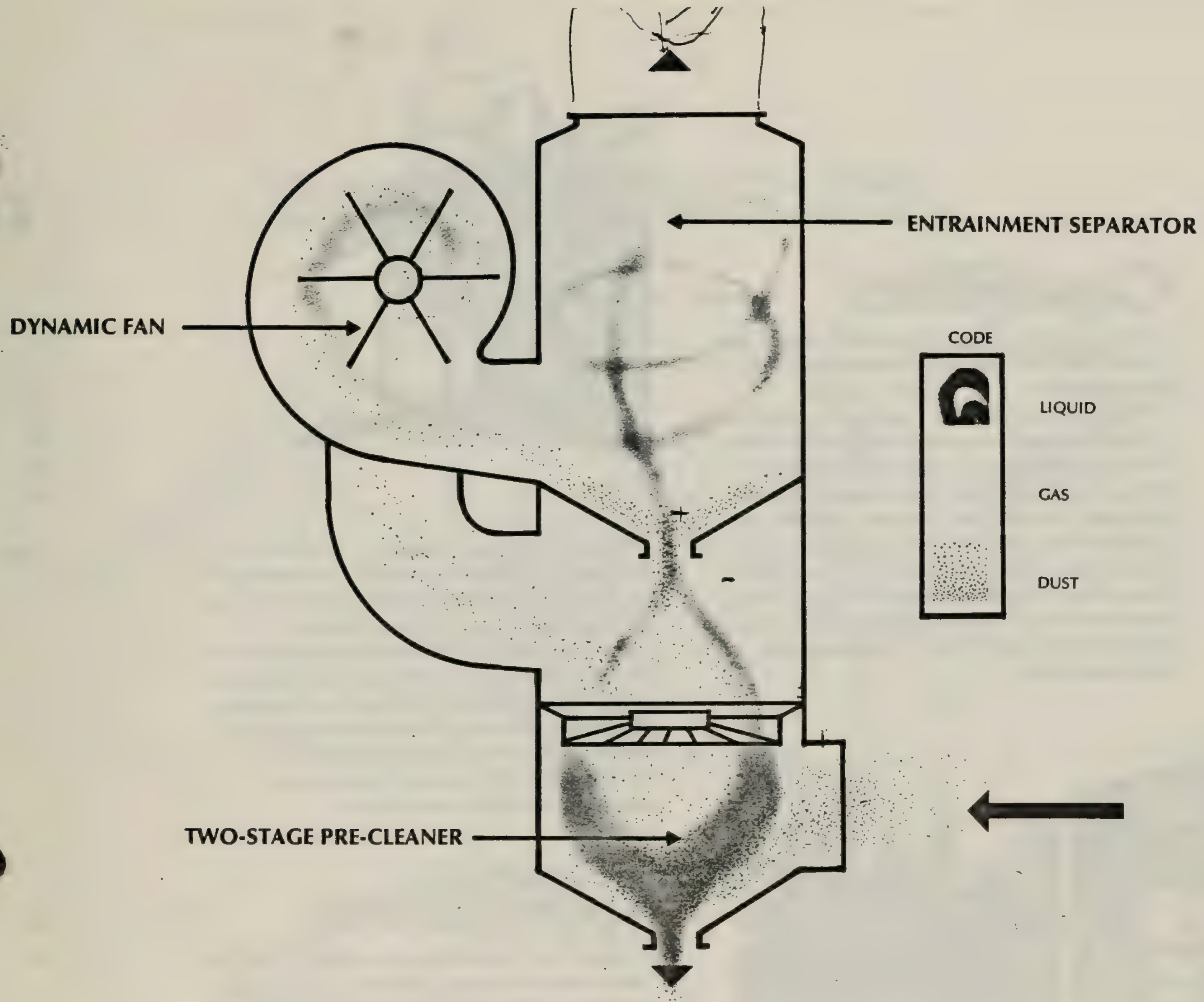


The wet "Dynamic Fan" combines the functions of exhaust system prime mover, atomization of scrubbing liquid and agglomeration of atomized liquid with suspended particulate matter. It not only promotes maximum scrubbing efficiency but it also eliminates the problems associated with exhaust fans installed in systems before or after gas scrubbers. When a fan is located on the high temperature inlet side of a scrubber, the fan is subject to considerable abrasion. Fans on the scrubber outlet side on the other hand, are subject to condensation and/or solids build-up on impeller blades with resulting wheel imbalance and in some case, corrosion. The UW-4 scrubber integral fan, however, never comes in contact with a mass of dry abrasive dust and is kept constantly and thoroughly wetted to protect against build-up and minimize the effects of corrosion.

Unique Vane Design



The wide open design of the conoidal impingement vane assures troublefree, non-plugging operation. Its efficiency and dependability has been proven in hundreds of difficult applications. Complete flushing of the vane in the UW-4 is another important factor in the elimination of build-up and plugging problems.



Two-Stage Pre-Cleaner

Dust-laden gases enter the lower part of the scrubber tangentially, resulting in a cyclonic flow thoroughly intermixed with scrubbing liquid. This forces the larger and more abrasive dust particles into the swirling liquid film on the surfaces and then, through the slurry outlet at the bottom. The gases pass through the scrubbing vane which provides: 1. Increased wetted surface area for particle impingement and 2. a swirling action for the mass of gas and liquid in the cylindrical section above. Here, intermediate size particles are collected and then flushed through the vane to the slurry discharge.

Dynamic Fan

The gases which are now conditioned, essentially saturated with water vapor and substantially free of large dust particles, are drawn into the interconnecting fan duct riser along with sufficient liquid from the bottom sections to flush clean the duct internal surfaces and to promote growth by agglomeration, of the remaining fine particles with liquid droplets.

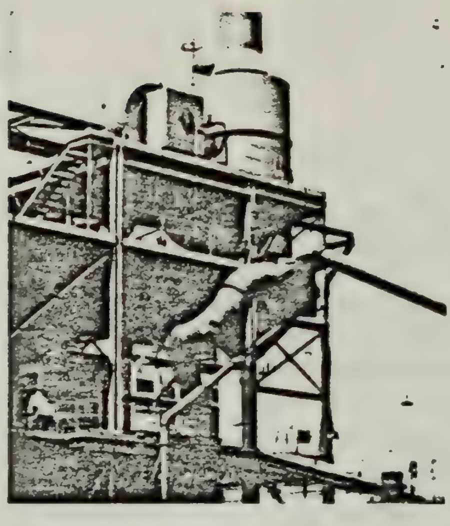
All of the scrubbing liquid for the unit is introduced into the "eye" of the fan, causing complete flushing (cleaning) of all the fan internal surfaces. Fine dust particles are then captured by:

1. Turbulent mixing of gases, liquid and dust particles causing liquid atomization and further particle "growth".
2. Impingement of fine dust particles on rotating wetted blades.
3. Centrifugal forces resulting from high fan wheel tip speeds causing impingement of dust particles and "agglomerates" on the moving film of water which completely covers the fan housing inside surfaces.

Entrainment Separator

The collected dust and liquid discharge from the fan tangentially into the final section of the scrubber where cyclonic action causes separation of slurry from the gas stream.

The entrainment separator increases gas velocity and directs gas flow so that entrained liquid droplets are thrown against the scrubber wall to descend and discharge through an intermediate cone orifice by gravity to become the liquid feed for the scrubbing vane below. Gases free of liquid droplets, discharge vertically through the scrubber gas outlet.

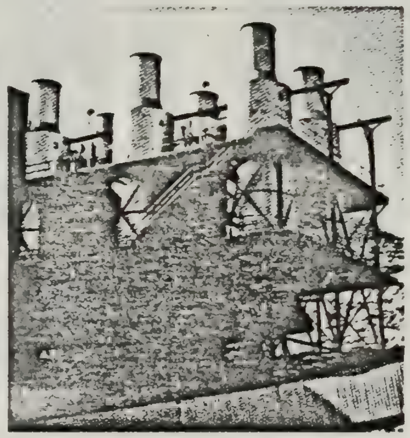


Capabilities

The Dynamic Scrubber, Type UW-4, Model IV is available with two performance capabilities, a standard and a high efficiency design.

The Dynamic Scrubber Type UW-4, Model IV High Efficiency, is an improved design which decreases outlet dust loadings up to 60% as compared to those obtained with prior standard efficiency models of the Dynamic Scrubber. As an example, in performance tests on talc dust, an average outlet dust loading of 0.016 gr/SCFD obtained with a standard Model IV Type UW-4 Scrubber was reduced to 0.006 gr/SCFD using the Model IV HE scrubber. This represents a reduction of 62%.

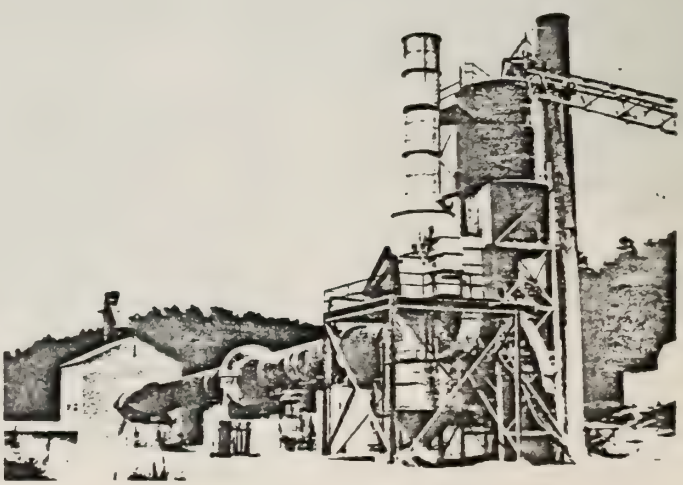
The improved performance of the Dynamic Scrubber, Type UW-4, Model IV HE results from improvements in configuration of unit internals and operating characteristics. The latter includes an increase in horsepower requirement (20-30%) and, in some instances, an increase in scrubbing liquid rate. However, the percentage increase in horsepower and scrubbing liquid requirements are far less than would be anticipated for the degree of improvement attained in scrubber performance.



Applications

A partial list of applications includes: calcium hypochlorite • carbon black • clay • copper concentrate dryers • dyes • fertilizer • fluorspar dryers • lime hydrators • limestone • paper grinding • pelletizing • phthalic anhydride • plastics • potash • silica flour • sintering • soda ash • titanium dioxide pigments

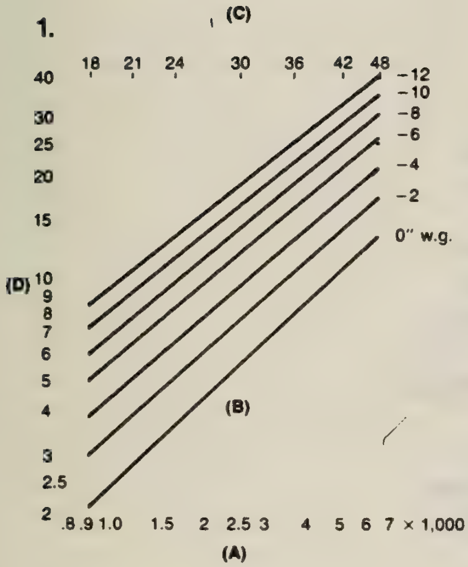
A Dynamic Scrubber, Type UW-4, Model IV Standard, handling exhaust gases from an expanded aggregate drying kiln, had outlet dust loadings averaging 0.101 gr/SCFD. After upgrading to a Model IV HE Dynamic Scrubber, the average outlet loadings were 0.026 gr/SCFD, a reduction of 75%.



SIZE AND HORSEPOWER SELECTION CHARTS FOR DYNAMIC SCRUBBER TYPE UW-4 MODEL IV

STANDARD DESIGN (UW-4S)

1.



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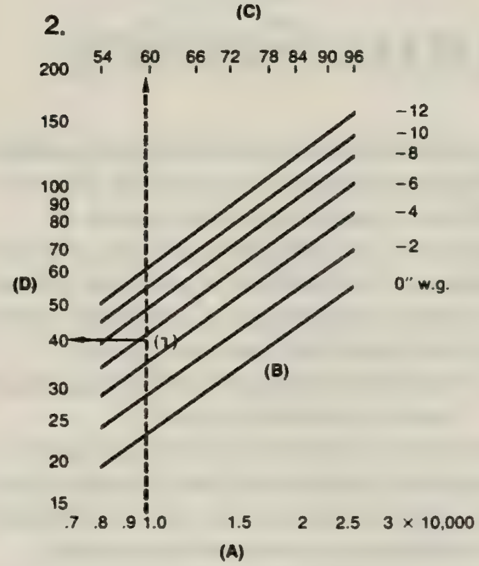
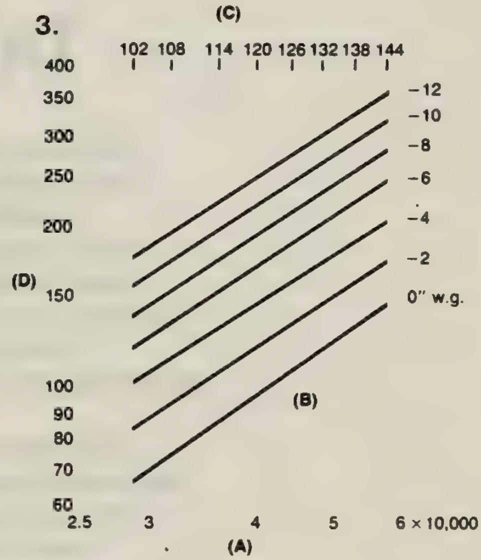
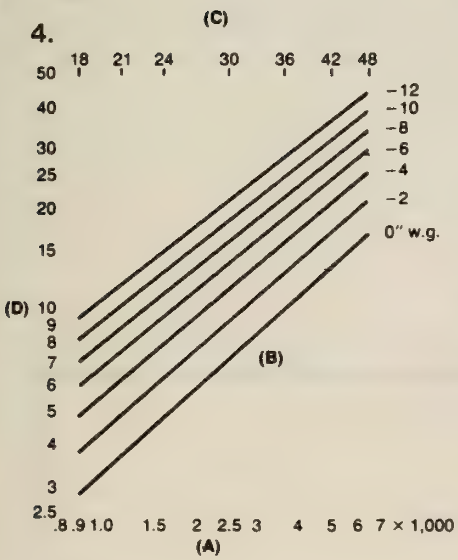


3.

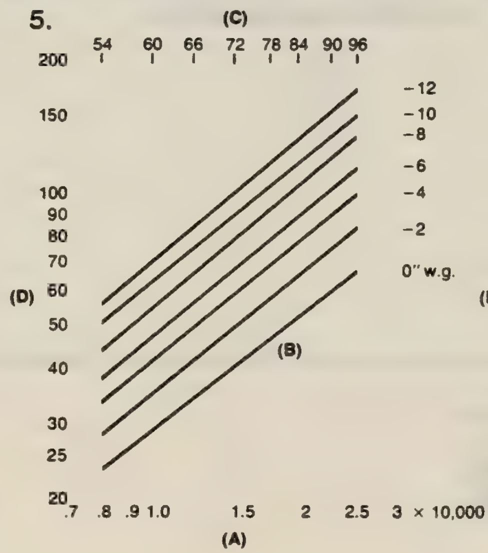


HIGH EFFICIENCY DESIGN (UW-4HE)

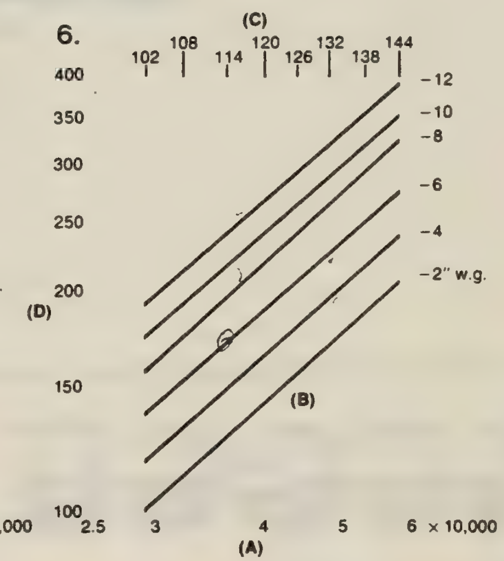
4.



5.



6.



Scale (A) Saturated Gas Volume, ACFM (Scrubber Outlet Conditions)
Curve (B) Inlet Static Pressure converted to standard conditions
Scale (C) Scrubber Size
Scale (D) Brake Horse Power (Gas Density—0.075 #/ft³)

HOW TO USE THE CHARTS

Example (see chart #2)
12,000 acfm at 300°F and −5" wg inlet static pressure and containing 15% water vapor by volume.
Barometer −29,92" Hg.

1. Calculate adiabatically saturated gas volume (scrubber outlet) —9,800 acfm at 138°F (gas density = 0.062 #/ft³)
2. Correct −5" wg inlet static pressure for density.
   $-5x\frac{.075}{.062} = -6.0$ wg at standard conditions (at fan inlet)
3. Enter chart on Scale A at 9,800 acfm.
4. Move vertically to 6.0" wg (Curve B-Point 1).
5. From Point 1 move vertically to Scale C and read scrubber Size 60.
6. From Point 1 move left to Scale D and read 42 B.H.P. (Density 0.075 #/ft³)
7. Select 50 H.P. motor.

Size and horsepower selection approximate.

Ducon Service

The Ducon Company has been solving dust control and air pollution problems for more than 40 years. In addition to supplying a broad range of control equipment, including the most versatile and complete selection of scrubbing equipment offered to industry, cyclones and pneumatic conveying systems, Ducon can supply the necessary system engineering and construction management for total engineered and/or installed systems.
Ducon maintains a large staff of sales and service engineering personnel experienced and capable of solving virtually any air pollution or dust control problem. service engineers are available for system services, start-ups, and troubleshooting assignments.
For expert engineering assistance and the highest quality of dust control and air pollution control products available, contact Ducon Mineola or our local representative.

The Ducon Company, Inc.
Subsidiary of U.S. Filter Corporation
147 East Second Street, Mineola, L.I., NY 11501
516-741-6100 TWX 510 9861

W-7578

West Coast Office:
10700 S.W. Beaverton Highway
Suite 675 Beaverton, Oregon 97005
503-643-1651

Canada: Ducon MikroPul Ltd.
1940 Steeles Avenue
Bramalea, Ontario, Canada L6T IA7
416-791-3883

Subsidiaries:
Ducon-MikroPul Pty, Sydney, Australia
Ducon-MikroPul Ltd., Ontario, Canada
MikroPul-Ducon Ltd., Shoeburyness, England
MikroPul-Ducon Eq. Ind. Ltda., Sao Paulo, Brazil

Licensees:
Germany, Italy, Japan, Mexico, New Zealand, Portugal, Spain, So. Africa

Member

3.0

APPENDIX 3.0

Emissions Calculations

APPENDIX 3.0
EMISSION CALCULATIONS
TABLE OF CONTENTS

APPENDIX 3.1

Fugitive Dust Emission Calculations

G-414
REV.11/62

Dravo
PITTSBURGH, PENNSYLVANIA

ENGINEERING COMPUTATIONS

EST NO. ______
CONT NO. M7541
DIVISION ______

COMPANY OCCIDENTAL OIL SHALE INC.
LOCATION RIO BLANCO COUNTY, COLO.
DESCRIPTION AIR POLLUTION EMISSION SOURCES

DATE 9-17-80 REV.4
DR LPG CH [illegible] 9-22-80
REF ______

REFERENCES

1. EPA REGION VIII INTERIM POLICY PAPER ON THE AIR QUALITY REVIEW OF SURFACE MINING OPERATIONS.
2. EPA AP-42 PART A, 3rd EDITION.
3. COLORADO AIR QUALITY CONTROL REGULATIONS AND AMBIENT AIR QUALITY STANDARDS.
4. IND. VENTILATION, 11th ED, AMER. CONF OF GOVT. INDUSTRIAL HYGIENISTS.

BASIS: 117,275 BPD SHALE OIL, 61,730 TPD ROCK w/ 55,900 TPD ROCK FROM MINE & 5830 TPD FROM RAW SHALE STOCKPILE

(1)(2) CONVEYORS #1 & 1A (PARTIALLY COVERED)

EMISSION FACTOR (E.F.) = 0.05 LB/TON (REF. 3)

UNCONT. DUST EMISSION $= (0.05\ LB/TON)(27{,}950\ TPD)(TON/2000\ LB)$

$= 0.70$ TPD × 350 DAYS/YR = 245.0 TPY

PROPOSE CHEMICAL SPRAY @ 85% EFF. & COVERED CONV. @ 90% EFF.

CONT. DUST EMISSION $= \left(\frac{100-85}{100}\right)\left(\frac{100-90}{100}\right)(0.70)$

$= 0.011$ TPD × 350 DAYS/YR = 3.85 TPY.

(3) CONV. #1 & 2 TRANSF. PTS. @ TRANSF. TOWER

E.F. = 0.15 LB/TON (REF. 3)

UNCONT. D.E. $= (0.15)(27{,}950)\left(\frac{1}{2000}\right) = 2.10$ TPD × 350
= 735.0 TPY

PROPOSE INSERTABLE BAGHOUSE @ 99.5% EFF. SIMILAR TO DCE VOKES.

CONT. D.E $= \left(\frac{100-99.5}{100}\right)(2.10) = 0.0105$ TPD × 350 = 3.67 TPY.

ALTERNATE: CHEMICAL SPRAY @ 85% = 0.315 TPD / 110.3 TPY

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⟨4⟩ CONV. # 1A & 2A TRANSF. PTS @ TRANSF. TOWER

E.F. = 0.15 LB/TON (REF. 3)

UNCONT. D.E. = $(0.15)(33780)\left(\frac{1}{2000}\right) = 2.53$ TPD × 350

= 885.5 TPY

PROPOSE INSERTABLE BAGHOUSE @ 99.5% EFF. SIMILAR TO DCE VOKES

CONT. D.E. = $\left(\frac{100-99.5}{100}\right)(2.53) = 0.0126$ TPD × 350 = 4.43 TPY

ALTERNATE: CHEMICAL SPRAY @ 85% = 0.38 TPD / 133.0 TPY

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5 CONV. # 2 (PARTIALLY COVERED)

E.F. = 0.05 LB/TON (REF. 3)

UNCONT. D.E. = $(0.05)(27{,}950)\left(\frac{1}{2000}\right) = 0.70$ TPD × 350
= 245.0 TPY

PROPOSE CHEMICAL SPRAY @ 85% & COVERED CONV. @ 90% EFF.

CONT. D.E. = $\left(\frac{100-85}{100}\right)\left(\frac{100-90}{100}\right)(0.70) = 0.011$ TPD × 350
= 3.85 TPY

6 CONV. # 2A (PARTIALLY COVERED)

E.F. = 0.05 LB/TON (REF. 3)

UNCONT. D.E. = $(0.05)(33{,}780)\left(\frac{1}{2000}\right) = 0.845$ TPD × 350
= 295.8 TPY

PROPOSE CHEMICAL SPRAY @ 85% & COVERED CONV. @ 90% EFF.

CONT. D.E. = $\left(\frac{100-85}{100}\right)\left(\frac{100-90}{100}\right)(0.845) = 0.013$ TPD × 350 = 4.55 TPY

7 8 STACKING TOWERS - LOAD-IN (TRANSF. PTS.)

E.F. = 0.15 LB/TON (REF. 3)

UNCONT. D.E. = $(0.15)\left(\frac{33{,}780}{2}\right)\left(\frac{1}{2000}\right) = 1.27$ TPD × 350
= 444.5 TPY

PROPOSE BAGHOUSE @ 99.5% EFF.

CONT. D.E. = $\left(\frac{100-99.5}{100}\right)(1.27) = 0.006$ TPD × 350 = 2.1 TPY

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⟨9⟩⟨10⟩ STACKING TOWERS - LOAD-IN (TRANSF. PTS.)

E.F. = 0.15 LB/TON (REF. 3)

UNCONT. D.E. = $(0.15)\left(\frac{27{,}950}{2}\right)\left(\frac{1}{2000}\right) = 1.05$ TPD × 350
= 367.5 TPY

PROPOSE BAGHOUSE @ 99.5% EFF.

CONT. D.E. = $\left(\frac{100-99.5}{100}\right)(1.05) = 0.005$ TPD × 350 = 1.75 TPY.

⟨11⟩ RAW SHALE TRUCK DUMPING TO CONV. #14

E.F. = $0.0018 \frac{\left(\frac{S}{5}\right)\left(\frac{U}{5}\right)}{\left(\frac{M}{2}\right)^2}$ LB/TON (REF. 3)

S = SILT CONTENT OF RAW SHALE = 3%

U = MEAN WIND SPEED = 10 MPH

M = SURFACE MOISTURE CONTENT OF RAW SHALE = 2% (ASSUMED)

∴ E.F. = $0.0018 \frac{\left(\frac{3}{5}\right)\left(\frac{10}{5}\right)}{\left(\frac{2}{2}\right)^2} = 0.00216$ LB/TON

UNCONT. D.E. = $(0.00216)(5830)\left(\frac{1}{2000}\right) = 0.0063$ TPD × 350
= 2.205 TPY

NO PROPOSED DUST CONTROL.

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(12) CONV. # 14 (PARTIALLY COVERED)

E. F. = 0.05 LB/TON (REF. 3)

UNCONT. D.E. = $(0.05)(5830)\left(\frac{1}{2000}\right)$ = 0.146 TPD × 350
= 51.1 TPY

PARTIALLY COVERED CONV. @ 90% EFF

CONT. D.E. = $\frac{(100-90)}{100}(0.146)$ = 0.0146 TPD × 350
= 5.11 TPY

(13) CONV. # 14 TRANSF. PT. @ TRANSF. TOWER

E. F. = 0.15 LB/TON (REF. 3)

UNCONT. D.E. = $(0.15)(5830)\left(\frac{1}{2000}\right)$ = 0.437 TPD × 350
= 152.95 TPY

PROPOSE INSERTABLE BAGHOUSE @ 99.5% EFF. SIMILAR TO DCE VOKES,

CONT. D.E. = $\frac{(100-99.5)}{100}(0.437)$ = 0.002 TPD × 350
= 0.70 TPY

ALTERNATE: CHEMICAL SPRAY @ 85% = 0.066 TPD / 23.1 TPY

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⟨14⟩⟨15⟩ CONV. #3 & 3A BOTTOM DUMP FROM STOCKPILE INSIDE TUNNEL

E.F. = 0.007 LB/TON (REF. 1)

UNCONT. D.E. = $(0.007)(30,865)\left(\frac{1}{2000}\right)$ = 0.108 TPD × 350
= 37.8 TPY

PROPOSE CHEMICAL SPRAY @ 85% EFF.

CONT. D.E. = $\left(\frac{100-85}{100}\right)(0.108)$ = 0.0162 TPD × 350 = 5.67 TPY

⟨16⟩ CONV. # 15 (PARTIALLY COVERED)

E.F. = 0.05 LB/TON (REF. 3)

CORR. FACTOR FOR 10% MOISTURE CONTENT = 0.044 (SEE SHTS 23 & 24)

DRY MATERIAL = 52,700 - 4685 = 48,015 TPD

UNCONT. D.E. = $(0.044)(0.05)(48,015)\left(\frac{1}{2000}\right)$ = 0.053 TPD × 350
= 18.55 TPY

PARTIALLY COVERED CONV. @ 90%

CONT. D.E. = $\frac{(100-90)}{100}(0.053)$ = 0.0053 TPD × 350
= 1.86 TPY

⟨17⟩⟨18⟩ CONV. # 3 & 3A (PARTIALLY COVERED)

E.F. = 0.05 LB/TON (REF. 3)

UNCONT. D.E. = $(0.05)(30865)\left(\frac{1}{2000}\right)$ = 0.772 TPD × 350
= 270.2 TPY

PROPOSE CHEMICAL SPRAY @ 85% & COVERED CONV. @ 90% EFF.

CONT. D.E. = $\left(\frac{100-85}{100}\right)\left(\frac{100-90}{100}\right)(0.772)$ = 0.0116 TPD × 350
= 4.06 TPY

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⟨19⟩ SECONDARY & TERTIARY CRUSHING & SCREENING AREA

BAGHOUSE AIR VOLUME = 142,000 ACFM

BAGHOUSE INLET DUST LOAD = 7.4 GR/CF (REF. 3)

$$\text{UNCONT. D.E.} = (142{,}000\ \text{ACFM})(7.4\ \text{GR/CF})\left(\frac{\text{LB}}{7000\ \text{GR}}\right)\left(\frac{\text{TON}}{2000\ \text{LB}}\right)(60\ \text{MIN/HR})(24\ \text{HR/DAY}) = 108.08\ \text{TPD} \times 350 = 37828\ \text{TPY}$$

PROPOSE BAGHOUSE @ 99.5% EFF.

$$\text{CONT. D.E.} = \left(\frac{100-99.5}{100}\right)(108.08) = 0.54\ \text{TPD} \times 350 = 189.0\ \text{TPY}$$

⟨20⟩⟨21⟩ CONV. #4 & 4A (PARTIALLY COVERED)

UNCONT. D.E = 0.772 TPD / 270.2 TPY (SAME AS ⟨17⟩)

PROPOSE WATER SPRAY @ 50% & COVERED CONV. @ 90% EFF.

$$\text{CONT. D.E.} = \left(\frac{100-50}{100}\right)\left(\frac{100-90}{100}\right)(0.772) = 0.0386\ \text{TPD} \times 350 = 13.51\ \text{TPY}$$

⟨22⟩ CONV. #6 (PARTIALLY COVERED)

TWO TIMES ⟨20⟩

UNCONT. D.E. = 2 × 0.772 = 1.544 TPD / 540.4 TPY

CONT. D.E = 2 × 0.0386 = 0.0772 TPD / 27.02 TPY (WATER SPRAY @ 50% & COV. CONV. @ 90%).

⟨23⟩ CONV. & TRANSF. POINTS @ TRANSF. TOWER

BAGHOUSE AIR VOLUME = 16,000 ACFM

BAGHOUSE INLET DUST LOAD = 7.4 GR/CF (REF. 3)

$$\text{UNCONT. D.E.} = (16{,}000)(7.4)\left(\frac{1}{7000}\right)\left(\frac{1}{2000}\right)(60)(24) = 12.18\ \text{TPD} \times 350 = 4262\ \text{TPY}$$

PROPOSE BAGHOUSE @ 99.5% EFF.

$$\text{CONT. D.E.} = \left(\frac{100-99.5}{100}\right)(12.18) = 0.061\ \text{TPD} \times 350 = 21.35\ \text{TPY}$$

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(24)(25) CONV. #15 TRANSF. POINTS

E.F. = 0.15 LB/TON (REF. 3)

CORR. FACTOR FOR 10% MOISTURE CONT. = 0.044 (SEE SHTS. 23 & 24)

DRY MATERIAL = 52,700 - 4685 = 48,015 TPD

$$\text{UNCONT. D.E.} = (0.044)(0.15)\left(\frac{48{,}015}{2\ \text{PTS.}}\right)\left(\frac{1}{2000}\right) = 0.079\ \text{TPD} \times 350$$

$$= 27.65\ \text{TPY}$$

NO PROPOSED DUST CONTROL.

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(26) 30,000 TON FINE STORAGE SILO LOAD-IN.

BIN FILTER AIR VOLUME = 1200 ACFM

FILTER INLET DUST LOAD = 7.4 GR/CF (REF. 3)

UNCONT. D.E. $= (1200)(7.4)\left(\frac{1}{7000}\right)\left(\frac{1}{2000}\right)(60)(24) = 0.91$ TPD × 350 = 318.5 TPY

PROPOSE BIN FILTER @ 99% EFF.

CONT. D.E. $= \left(\frac{100-99}{100}\right)(0.91) = 0.009$ TPD × 350 = 3.15 TPY

(27)(28) 30,000 TON FINE STORAGE SILO LOAD-OUT

E.F. = 0.007 LB/TON (REF. 1)

UNCONT. D.E. $= (0.007)(30865)\left(\frac{1}{2000}\right) = 0.108$ TPD × 350 = 37.8 TPY

PROPOSE INSERTABLE BAGHOUSE @ 99.5% EFF. SIMILAR TO DCE VOKES

CONT. D.E. $= \left(\frac{100-99.5}{100}\right)(0.108) = 0.0005$ TPD × 350 = 0.175 TPY

ALTERNATE: CHEMICAL SPRAY @ 85% = 0.0162 TPD / 5.67 TPY

(29) SPENT SHALE HANDLING & DISPOSAL AREA

SCRUBBER AIR VOLUME = 32,000 ACFM

SCRUBBER INLET DUST LOAD = 4.4 GR/CF (EST.)

UNCONT. D.E. $= (32,000)(4.4)\left(\frac{1}{7000}\right)\left(\frac{1}{2000}\right)(60)(24) = 14.48$ TPD × 350 = 5068 TPY

PROPOSE WET SCRUBBER @ 98.0% EFF.

CONT. D.E. $= \left(\frac{100-98}{100}\right)(14.48) = 0.29$ TPD × 350 = 101.5 TPY

30 SPENT SHALE DISPOSAL - LOAD-IN TO STORAGE BIN

E.F. = 0.15 LB/TON (REF. 3)

CORR. FACTOR FOR 10% MOISTURE CONTENT = 0.044 (SEE SHTS. 23 & 24)

DRY MATERIAL = 52,700 - 4685 = 48,015 TPD

UNCONT. D.E. $= (0.044)(0.15)(48,015)\left(\frac{1}{2000}\right) = 0.158$ TPD × 350
= 55.3 TPY

NO PROPOSED CONTROL.

31 SPENT SHALE DISPOSAL - LOAD-OUT FR. BINS TO 120 TON TRUCKS

E.F. = 0.007 LB/TON (REF. 1); MOISTURE CORR. FACTOR = 0.044

DRY MATERIAL = 52,700 - 4685 = 48,015 TPD

UNCONT. D.E. $= (0.044)(0.007)(48,015)\left(\frac{1}{2000}\right) = 0.0074$ TPD × 350
= 2.59 TPY

NO PROPOSED CONTROL.

32 SPENT SHALE DISPOSAL - 120 TON TRUCKS TO STOCKPILE (VEHICULAR TRAFFIC)

$$E.F. = \frac{sS}{60}\left(\frac{365-w}{365}\right) \text{ IN LB/VMT (REF. 1)}$$

VMT = VEHICLE MILES TRAVELLED.

s = SILT CONTENT OF ROAD = 8 TO 25% FOR DIRT HAUL ROAD (REF. 3), USE 10%

S = AVE. VEHICLE SPEED = 15 MPH

365 - w = 230 DRY DAYS / YEAR (REF. 3)

∴ w = 135 MEAN ANNUAL NO. OF DAYS W/ >0.01" RAIN

$$\therefore E.F. = \frac{(10)(15)(365-135)}{(60)(365)} = 1.575 \text{ LB/VMT}$$

(32) CONT.

$$VMT/TRIP = (1.1)(9850')(2)\left(\frac{MILE}{5280\,FT}\right) = 4.1\ MILE/TRIP$$

$$VMT/DAY = \left(4.1\frac{MILE}{TRIP}\right)(52700\ TPD)\left(\frac{1}{120\ TON/TRIP}\right) = 1800\ VMT/DAY$$

$$UNCONT.\ D.E. = \left(1.575\frac{LB}{VMT}\right)\left(1800\frac{VMT}{DAY}\right)\left(\frac{TON}{2000\,LB}\right)$$

$$= 1.418\ TPD \times 350 = 496.3\ TPY$$

PROPOSE CHEMICAL SPRAY @ 85%

$$CONT.\ D.E. = \left(\frac{100-85}{100}\right)(1.418) = 0.213\ TPD \times 350 = 74.55\ TPY$$

(33) SPENT SHALE DISPOSAL - STOCKPILE DUMPING, SCRAPING, & SHAPING

WIND EROSION (UNCOVERED)

UNCOVERED STOCKPILE = 50 ACRES (7 RETORTS) w/ 5 MOS. SNOW COVER

$$E.F. = \frac{3400\left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)(K_s)}{(PE/50)^2\,(2000)}\ TONS/ACRE\text{-}YR\ (REF.\ 3)$$

e = SURFACE ERODIBILITY, FROM SILT = 38 TO SAND = 220
USE 100.

s = SILT CONTENT = 25%

f = % OF TIME WIND SPEED EXCEEDS 12 MPH
USE 25%

PE = PRECIP./EVAP. INDEX = 51 (FROM CHART).

K_s = CORR. FOR 5 MOS. SNOW COVER = $\frac{12-5}{12}$

$$\therefore EF = \frac{3400\left(\frac{100}{50}\right)\left(\frac{25}{15}\right)\left(\frac{25}{25}\right)\left(\frac{12-5}{12}\right)}{(51/50)^2\,(2000)} = 3.18\ TON/ACRE\text{-}YR.$$

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(33) CONT.

$$\text{UNCONT. D.E.} = 3.18\ \frac{\text{TON}}{\text{ACRE-YR}} \times 50\ \text{ACRE} = 159\ \text{TPY} \times \frac{1}{365} = 0.436\ \text{TPD.}$$

PROPOSE WATER SPRAY @ 50%

$$\text{CONT. D.E.} = \left(\frac{100-50}{100}\right)(0.436) = 0.218\ \text{TPD} \times 365 = 79.57\ \text{TPY}$$

(34) RAW SHALE - STOCKPILE DUMPING, SCRAPING, & SHAPING

WIND EROSION (UNCOVERED)

UNCOVERED STOCKPILE = 15 ACRES w/ 5 MOS. SNOW COVER

$$E.F. = \frac{3400\left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)(K_s)}{(PE/50)^2(2000)}\ \text{TONS/ACRE-YR (REF. 3)}$$

SEE (33) FOR DEFINITION OF SYMBOLS

$e = 100$

$s = 3\%$

$f = 25\%$

$PE = 51$

$K_s = \frac{12-5}{12}$

$$\therefore E.F. = \frac{(3400)\left(\frac{100}{50}\right)\left(\frac{3}{15}\right)\left(\frac{25}{25}\right)\left(\frac{12-5}{12}\right)}{(51/50)^2(2000)} = 0.381\ \text{TONS/ACRE-YR}$$

$$\text{UNCONT. D.E.} = 0.381\ \frac{\text{TON}}{\text{ACRE-YR}} \times 15\ \text{ACRES} = 5.72\ \text{TPY} \times \frac{1}{365} = 0.0157\ \text{TPD}$$

PROPOSE WATER SPRAY @ 50%

$$\text{CONT. D.E.} = \left(\frac{100-50}{100}\right)(0.0157) = 0.0079\ \text{TPD} \times 365 = 2.88\ \text{TPY}$$

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35 36 CONV. # 16 TRANSF. POINTS

SAME AS 24 25

UNCONT. D. E. = 0.079 TPD / 27.65 TPY

NO PROPOSE DUST CONTROL.

37 CONV. # 16 (PARTIALLY COVERED)

SAME AS 16

UNCONT. D.E. = 0.053 TPD / 18.55 TPY

CONT. D.E. = 0.0053 TPD / 1.86 TPY

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(38) TOPSOIL REMOVAL - SCRAPER/LOADER FROM SPENT SHALE AREA

TOPSOIL REMOVED = 85,000 CY/YR (35 ACRES)

E.F. = 0.38 LB/CY (REF. 1)

UNCONT. D.E. $= (0.38)(85000)\left(\frac{1}{2000}\right) = 16.15$ TPY $\div 260 = 0.062$ TPD

NO PROPOSE DUST CONTROL

(40) TOPSOIL - STOCKPILE DUMPING & WIND EROSION (REVEGETATED)

NO EMISSION - AREA IS FULLY REVEGETATED AFTER 10 YEARS.

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(41) TOPSOIL - EMISSION FROM VEHICULAR TRAFFIC OVER SPENT SHALE STOCKPILE

$$E.F. = 1.575 \text{ LB/VMT} \quad (\text{SEE } \langle 32 \rangle)$$

$$VMT/TRIP = (1.1)(4200)(2)\left(\frac{\text{MILE}}{5280 \text{ FT}}\right) = 1.75 \text{ MILE/TRIP}$$

$$VMT/DAY = \left(1.75 \frac{\text{MILE}}{\text{TRIP}}\right)\left(\frac{85{,}000 \text{ CY/YR} \times 2 \text{ TON/CY}}{260 \text{ DAYS/YR}}\right)\left(\frac{1}{120 \text{ TON/TRIP}}\right) = 9.5 \text{ VMT/DAY}$$

$$\text{UNCONT. D.E.} = (1.575 \text{ LB/VMT})(9.5 \text{ VMT/DAY})\left(\frac{\text{TON}}{2000 \text{ LB}}\right) = 0.0075 \text{ TPD}$$

$$\times 260 \text{ DAYS/YR} = 1.95 \text{ TPY}$$

PROPOSE CHEMICAL SPRAY @ 85%

$$\text{CONT. D.E.} = \left(\frac{100-85}{100}\right)(0.0075) = 0.0011 \text{ TPD} \times 260 = 0.385 \text{ TPY}$$

(42) TOPSOIL - DUMPING, SCRAPING, SHAPING, WIND EROSION (UNCOVERED) ON SPENT SHALE FOR REVEGETATION

$$E.F. = 0.12 \times \frac{0.33}{(PE/100)^2} \text{ LB/TON (REF. 1)} \; ; \; PE = 51$$

$$= 0.12 \times \frac{0.33}{(51/100)^2} = 0.152 \text{ LB/TON}$$

$$\text{UNCONT. D.E.} = (0.152 \text{ LB/TON})\left(\frac{85000 \text{ CY/YR} \times 2 \text{ TON/CY}}{260 \text{ DAYS/YR}}\right)\left(\frac{\text{TON}}{2000 \text{ LB}}\right)$$

$$= 0.05 \text{ TPD} \times 260 = 13.0 \text{ TPY}$$

NO PROPOSED DUST CONTROL.

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43 44 MINE EXHAUST SHAFTS (NO. 1 & NO. 2)

1. No. 2 Diesel Comb. Products

NO. 2 DIESEL BASIS: 11300 GPD / 51200 TPD (FROM PREVIOUS CALCS. BY J. MONTGOMERY - DRAVO).

FOR 59000 TPD $= \frac{(55900/2)}{51200} \times 11300$ GPD = 6169 GPD / SHAFT.

Emission FACTOR FOR DIESEL-POWERED VEHICLES FROM REF. 2 TABLE 3.2.7.1 (UNDER MISC VEHICLES).

$CO = 94.2$ lb/10^3 GAL.
UB HC = 34.7 lb/10^3 GAL
NO_2 = 494 Lb/10^3 GAL
HCHO = 6.78 lb/10^3 GAL (ALDEHYDES)
SO_2 = 31.1 Lb/10^3 GAL
PART. = 30.1 lb/10^3 GAL

CO: 6169 GPD × 94.2 lb/10^3 GAL × $\frac{TON}{2000 Lb}$ = 0.291 TPD × 350
= 101.85 TPY
= 0.0120 TPH
= 0.096 T/8HR

UBHC: 6169 × 34.7/10^3 × $\frac{1}{2000}$ = 0.107 TPD × 350
= 37.45 TPY
= 0.0045 TPH
= 0.036 T/8HR

NO_X: 6169 × 494/10^3 × $\frac{1}{2000}$ = 1.524 TPD × 350
= 533.4 TPY
= 0.064 TPH
= 0.512 T/8HR

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HCHO: $6169 \times 6.78/10^3 \times \frac{1}{2000}$ = 0.021 TPD × 350
= 7.35 TPY
= 0.0009 TPH
= 0.0072 T/8HR

SO_2: $6169 \times 31.1/10^3 \times \frac{1}{2000}$ = 0.096 TPD × 350
= 33.6 TPY
= 0.004 TPH
= 0.032 T/8HR

PART: $6169 \times 30.1/10^3 \times \frac{1}{2000}$ = 0.093 TPD × 350
= 32.55 TPY
= 0.004 TPH
= 0.032 T/8HR.

2. MINE DUST

TOTAL EXH. AIR = 4.9 MMSCFM
EACH SHAFT = 2.45 MMSCFM
MAX. MINE DUST = 2 MG/m^3 (REF. 4).

$$\text{MINE DUST} = 2.45 \times 10^6 \text{ SCFM} \times \frac{60 \text{ min}}{\text{HR}} \times \frac{24 \text{ HR}}{\text{DAY}} \times \frac{2 \text{ MG} \times .001 \text{ GR/MG} \times .0022 \text{ lbs/GR}}{m^3 \times 35.31 \text{ CF}/m^3 \times 2000 \text{ lb/Ton}}$$

= 0.220 TPD × 350 = 77 TPY
= 0.009 TPH = 0.072 T/8HR.

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3. BLASTING (117,275 BPD/ 55,900 TPD)

BASIS: 55,423 BPD/66 RETORTS
51200 LB. ANFO/DAY ; ONE RETORT/5.3 DAYS
NORMAL CHG: 1 LB. ANFO/TON ROCK & 454,000 LB ANFO/RETORT
2 LB DUST/1000 LB. ANFO.

No. OF RETORTS REQD. FOR 117,275 BPD

$$= \frac{117,275 \text{ BPD}}{55,423 \text{ BPD}} \times 66 \text{ RETORTS} = 140 \text{ RETORTS}$$

$$\text{TIME SPAN/RETORT} = \frac{350 \text{ DAYS}}{140 \text{ RETORTS}} = 2.5 \text{ DAYS/RETORT}$$

a. TOTAL DUST (AVG.) = DUST PROD. DRIFTING + DUST PROD. RETORTS

$$= 55,900 \text{ TPD} \times 1.0 \text{ LB. ANFO/TON} \times 2 \text{ LB. DUST}/1000 \text{ LB ANFO.}$$
$$+ 454,000 \text{ LB. ANFO/RETORT} \times \frac{2 \text{ LB. DUST}}{1000 \text{ LB. ANFO}} \times \frac{\text{RETORT}}{2.5 \text{ DAYS}}$$
$$= 112 + 363 = \frac{475 \text{ LB/DAY}}{2 \text{ SHAFTS}} = 237.5 \frac{\text{LB/DAY}}{\text{SHAFT}}$$

$$\text{TPD} = 237.5/2000 = 0.119 \text{ TPD}$$
$$\text{TPY} = 0.119 \times 350 = 41.65 \text{ TPY}$$

b. NO_x

$$NO_x = 0.05335 \text{ MOLES/KGM} \times 0.36 = 0.0192 \text{ CUFT/LB ANFO}$$
$$NO_x = \left(\frac{0.0192 \text{ CUFT}}{\text{LB. ANFO}}\right)\left(\frac{0.0837 \text{ LB}}{\text{CUFT}}\right)\left(\frac{454,000 \text{ LB. ANFO/RET.}}{2.5 \text{ DAYS/RET}}\right)\left(\frac{\text{TON}}{2000 \text{ LB}}\right)\left(\frac{1}{2 \text{ SHAFTS}}\right)$$
$$= 0.073 \text{ TPD} \times 350 = 25.55 \text{ TPY}$$

c. CO

$$CO = 0.761 \text{ MOLES/KGM} \times 0.36 = 0.274 \text{ CUFT/LB. ANFO.}$$
$$CO = \left(\frac{0.274 \text{ CUFT}}{\text{LB. ANFO}}\right)\left(\frac{0.0781 \text{ LB}}{\text{CUFT}}\right)\left(\frac{454,000 \text{ LB ANFO/RET.}}{2.5 \text{ DAYS/RET.}}\right)\left(\frac{\text{TON}}{2000 \text{ LB}}\right)\left(\frac{1}{2 \text{ SHAFTS}}\right)$$
$$= 0.972 \text{ TPD} \times 350 = 340.2 \text{ TPY}$$
$$\text{TPH} = 0.972 \text{ TPD} \times 2.5/24 = 0.101 \text{ TPH} \quad (\text{MAX})$$
$$\text{T/8HR} = 0.101 \times 8 = 0.808 \text{ T/8HR.}$$

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(45) RAW SHALE - STOCKPILE EMISSION TO CONV. #14 (VEHICULAR TRAFFIC)

$E.F. = 1.575$ LB/VMT (SEE (32))

$VMT/TRIP = (1.1)(1200')(2)\left(\frac{MILE}{5280\ FT}\right) = 0.5$ MILE/TRIP

$VMT/DAY = \left(0.5\frac{MILE}{TRIP}\right)(5830\ TPD)\left(\frac{1}{120}\right) = 24.3$ VMT/DAY.

$UNCONT.\ D.E. = (1.575\ LB/VMT)\left(24.3\frac{VMT}{DAY}\right)\left(\frac{TON}{2000\ LB}\right) = 0.019\ TPD \times 350$
$= 6.65\ TPY$

PROPOSE CHEMICAL SPRAY @ 85%

$CONT.\ D.E. = \left(\frac{100-85}{100}\right)(0.019) = 0.0028\ TPD \times 350 = 0.98$ TPY.

(47) TOPSOIL REMOVAL - SCRAPER LOADER FROM RAW SHALE STOCKPILE

$E.F. = 0.38$ LB/CY (REF. 1)

$TOPSOIL\ REMOVAL = 68000\ CY/YR\left(\frac{5830\ TPD}{36000\ TPD}\right) = 11000\ CY/YR$ (5 ACRES)

$UNCONT.\ D.E. = (0.38)(11000)\left(\frac{1}{2000}\right) = 2.09\ TPY \div 260$
$= 0.008\ TPD$

NO PROPOSED DUST CONTROL.

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(49) TOPSOIL - EMISSION FROM VEHICULAR TRAFFIC OVER RAW SHALE STOCKPILE

$E.F. = 1.575$ LB/VMT (SEE ⟨32⟩)

$VMT/TRIP = (1.1)(1200')(2)\left(\frac{1}{5280}\right) = 0.5$ MILE/TRIP

$VMT/DAY = (0.5 \text{ MILE/TRIP})\left(\frac{11\,000 \text{ CY/YR} \times 2 \text{ TON/CY}}{260 \text{ DAYS/YR}}\right)\left(\frac{1}{120}\right) = 0.353$ VMT/DAY

$UNCONT\ D.E. = (1.575 \text{ LB/VMT})\left(0.353 \frac{VMT}{DAY}\right)\left(\frac{1}{2000}\right) = 0.0003 \text{ TPD} \times 260$

$= 0.078$ TPY

PROPOSE WATER SPRAY @ 50%

$CONT.\ D.E. = \left(\frac{100-50}{100}\right)(0.0003) = 0.00015 \text{ TPD} \times 260 = 0.039 \text{ TPY}$

⟨50⟩ TOPSOIL - DUMPING, SCRAPING, SHAPING, WIND EROSION FROM RAW SHALE STOCKPILE

$E.F. = 0.152$ LB/TON (SEE ⟨42⟩) (5 ACRES).

$UNCONT.\ D.E. = (0.152)\left(\frac{11{,}000 \text{ CY/YR} \times 2 \text{ TON/CY}}{260}\right)\left(\frac{1}{2000}\right) = 0.0064 \text{ TPD}$

$\times 260 = 1.67$ TPY

PROPOSE WATER SPRAY @ 50%

$CONT.\ D.E. = \left(\frac{100-50}{100}\right)(0.0064) = 0.0032 \text{ TPD} \times 260 = 0.832 \text{ TPY}.$

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51 SURFACE DIESEL-POWERED CONST. EQUIPT. EMISSION

DIESEL-POWERED CONST. EQUIPT. FROM EQUIPT. LIST.

8 - 120 TON END DUMP TRUCKS @ 25 GPH
2 - D9 DOZER @ 35 GPH
1 - GRADER (14' BLADE) @ 35 GPH
1 - WATER TRUCK (5000 GAL. TANK). @ 25GPH

FROM REF. 2. TABLE 3.2.7-1 EMISSION FACTOR FOR DIESEL-POWERED CONST. EQUIPT.

A. OFF-HIGHWAY TRUCK (120 TON E.D. TRUCKS & WATER TRUCK).

CO = 92.2 lb/1000 GAL
NO_x = 524 "
SO_2 = 31.2 "
PART. = 17.7 "

B. WHEELED DOZER (D9 DOZER)

CO = 65.9 lb/1000 GAL
NO_x = 450 "
SO_2 = 31.2 "
PART. = 14.8 "

C. MOTOR GRADER (14' BLADE GRADER)

CO = 78 LB/1000 GAL
NO_x = 374 "
SO_2 = 31.1 "
PART. = 22.2 "

ALL ABOVE EQUIPT. WILL BE USED 24 HR/DAY, 350 DAYS/YR.

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(51) CONTINUED.

$$\underline{\underline{CO}} = \Big(8 \times 25\,GAL/HR \times \frac{92.2\,lb}{1000\,GAL} + 1 \times 25\,GAL/HR \times \frac{92.2\,lb}{1000\,GAL} +$$

$$2 \times 35\,GAL/HR \times \frac{65.9\,LB}{1000\,GAL} + 1 \times 35\,GAL/HR \times \frac{78\,LB}{1000\,GAL}\Big)\left(\frac{TON}{2000\,LB}\right)$$

$= 0.014$ TPH $\times 8 = 0.112$ TON/8HR

$= 0.014$ TPH $\times 24 = 0.336$ TPD $\times 350 = 117.6$ TPY

$$\underline{\underline{NO_x}} = \left(8 \times 25 \times \frac{524}{1000} + 1 \times 25 \times \frac{524}{1000} + 2 \times 35 \times \frac{450}{1000} + 1 \times 35 \times \frac{374}{1000}\right)\left(\frac{1}{2000}\right)$$

$= 0.081$ TPH $\times 8 = 0.648$ TON/8 HR

$= 0.081$ TPH $\times 24 = 1.944$ TPD $\times 350 = 680.4$ TPY

$$\underline{\underline{SO_2}} = \left(8 \times 25 \times \frac{31.2}{1000} + 1 \times 25 \times \frac{31.2}{1000} + 2 \times 35 \times \frac{31.2}{1000} + 1 \times 35 \times \frac{31.1}{1000}\right)\left(\frac{1}{2000}\right)$$

$= 0.005$ TPH $\times 8 = 0.04$ TON/8HR

$= 0.005$ TPH $\times 24 = 0.12$ TPD $\times 350 = 42$ TPY

$$\underline{PART.} = \left(8 \times 25 \times \frac{17.7}{1000} + 1 \times 25 \times \frac{17.7}{1000} + 2 \times 35 \times \frac{14.8}{1000} + 1 \times 35 \times \frac{22.2}{1000}\right)\left(\frac{1}{2000}\right)$$

$= 0.003$ TPH $\times 8 = 0.024$ TON/8HR

$= 0.003$ TPH $\times 24 = 0.072$ TPD $\times 350 = 25.2$ TPY

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MOISTURE CONTENT ADJUSTMENT FOR SPENT SHALE DISPOSAL

THE FOLLOWING CALCS. PROVIDE THE ADJUSTMENT NECESSARY FOR SPENT SHALE EMISSION POINTS WHICH ARE INFLUENCED BY MOISTURE CONTENT. IT HAS BEEN RECOMMENDED THAT THE MOISTURE CONTENT OF THE SPENT SHALE BE ESTABLISHED AT 10% BY WEIGHT, AS THE SHALE IS CONVEYED FROM THE RETORTS TO THE DISPOSAL PILE WHERE THE MATERIAL IS TAMPED DOWN AND REVEGETATED. THERE IS LIMITED CORRELATION DATA AVAILABLE BETWEEN SPENT SHALE OR ANY OTHER SOILS EMITTING DUST AND THEIR MOISTURE CONTENT. HOWEVER, THERE IS A CORRELATION OFFERED BY DR. CHATTEN COWHERD JR. OF MIDWEST RESEARCH INST. (EPA-450/3-74-037) BETWEEN SANDY LOAMY, HIGH SILT CONTENT SOILS OF VARYING MOISTURE CONTENT AND THORNTHWAITE'S PE (PRECIPITATION-EVAPORATION INDEX).

MOISTURE (% BY WT.)	EQUIV. PE INDEX
10.5	40
11.0	41
12.3	46
13.4	50
15.9	59

THE EMISSION FACTOR FOR DRY MATERIAL VARIES INVERSELY AS THE SQUARE OF THE PE INDEX,

$$\text{EMISSION FACTOR LB/TON} = \frac{1}{(PE)^2}$$

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IT WAS ASSUMED THAT THE MOISTURE CONTENT OF DRY SOILS OR TAILINGS IS ABOUT 2%. BY EXTRAPOLATION OF COWHERD DATA, THE EQUIVALENT PE INDEX FOR 2% IS 8.

THEREFORE, THE ADJUSTMENT FOR 10% MOISTURE CONTENT WITH EQUIV. PE INDEX OF 38 (BY EXTRAPOLATION) WILL BE

$$= \frac{(PE)^2_{2\%}}{(PE)^2_{10\%}} = \frac{(8)^2}{(38)^2} = \underline{\underline{0.044}}$$

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

3.2 FGD and Surface Processing Facilities

For four Trains of FGD units:

Total (Wet) Flow = 4.853×10^9 SCFD

Temp = 163°F

SO_2 = 21.4 moles / hr

Flow / train:

$$\left(\frac{4.853 \times 10^9 \text{ SCFD}}{4}\right)\left(\frac{623°R}{520°R}\right)\left(\frac{14.7 \text{ psia}}{11 \text{ psia}}\right)\left(\frac{1 \text{ Day}}{24 \text{ hr}}\right)\left(\frac{1 \text{ hr}}{3600 \text{ sec}}\right) = \underline{22.5 \times 10^3 \text{ acfs}}$$

$$(22.5 \times 10^3)(.02832 \text{ m}^3/\text{ft}^3) = \underline{637 \text{ m}^3/\text{sec}}$$

°K : °C + 273 = 72.8 + 273 = $\underline{346°K}$

SO_2: 64 lb/mole

@ 21.4 moles/hr = $\underline{1372.2}$ lb/hr

= $\underline{0.381}$ lb/sec/4 trains

$$\left(454 \frac{\text{gm}}{\text{lb}}\right)\frac{(0.388 \text{ lb/sec/4 Trains})}{4} = \underline{43.3} \text{ gm/sec/ train}$$

NO_x: Our consultants indicate that the most realistic estimate of NO_x in the boiler flue gas is a range of from 0.5 to 1 lb/10^6 BTU. For this estimate, the average of 0.75 lb/10^6 BTU will be used. Work is continuing into the design of the burners to achieve even lower NO_x emissions.

Gas Feed to the Boilers:

Phosam	- 14.1×10^6 scfd	47 BTU/scf	662.7×10^6 BTU/D
Lurgi	- 67.58×10^6 scfd	750 BTU/scf	$50,685 \times 10^6$ BTU/D
MIS	- 2306×10^6 scfd	59 BTU/scf	$136,054 \times 10^6$ BTU/D
		Total	$187,401 \times 10^6$ BTU/D

For Five Units:

$$\left(\frac{5}{4}\right)(187401 \times 10^6 \text{ BTU/D}) = \underline{221,580.9 \times 10^6} \text{ BTU/D}$$

$$@\ 0.75\ \#/10^6 \quad NO_x \quad = \underline{166,185.68\ \text{lb/D}}\ \cdot NO_x$$
$$= \underline{83.09\ T}/D \quad \Leftarrow$$

Total NO_x emissions:

FGD	83.09 T/D
Mine Vents	3.2 T/D
Lurgi Waste Gas	4.62 T/D
Total	90.91 T/D $\Leftarrow$

Boiler Particulate Emissions:

Particulates for Natural Gas - AP-42

$5\text{-}15\ \#/10^6\ ft^3$

MIS Gas:

Five trains - (2306×10^6 SCFD for four trains)$\left(\frac{5}{4}\right)$ = 2882.5×10^6 scf.

Volume % of Inert constituents (MIS):

H_2	8.10
H_2S	0.17
CO_2	29.10
$N_2 + NH_3$	57.98
	95.35

$\Rightarrow$ 134.04 $\times 10^6$ scfd HCBN

Lurgi Produced Gas:

67.58 $\times 10^6$ scfd (7 units)

Volume % of Inert constituents:

N_2	3.1
CO_2	25.5
H_2	31.5
H_2S	.072
SO_2	.060
NH_3	.25
	60.482

$\Rightarrow$ 26.706 $\times 10^6$ scfd HCBN

Phosam Produced Gas:

14.1 $\times 10^6$ scfd

Volume % of Inert constituents:

CO_2	96.3
~~H_2O~~ NH_3	1.9
	98.2

$\Rightarrow$ 0.254 $\times 10^6$ scfd HCBN

EJ 1/13/81

Total Combustible Gas: 161.01×10^6 scfd

Assume 10 lb/10^6 scf

$\Rightarrow$ 1610.1 lb/day

$\Rightarrow$ 587686.5 lb/year

$\Rightarrow$ 293.84 T/year

Total:

$$\left(\frac{1610.1\ lb}{Day}\right)\left(\frac{day}{24\,hr}\right)\left(\frac{hr}{3600\,sec}\right)\left(\frac{453.6\ gm}{lb}\right) = 8.45\ gm/sec$$

1.69 gm/sec/stac.

EF 1/13/8

3.3 Above Ground Retorting – AGR

Stream quantities and qualities have been provided by Lurgi Kohle und Mineralöltechnik GmbH.

Lurgi Unit Flue Gas:

Quantity of gas per train: 146,000,000 (wet) scfd

The flow is saturated:

Reduction of volume is based on ratio from "Perry's", Thermodynamic Properties of Moist Air – Table 15-1, page 15-6

$$\left[1 - \frac{5.211}{20.58}\right] = 0.747$$

$$(0.747)(146,000,000) = 109,032,000 \text{ scfd (dry)}$$

SO_2:

SO_2 is 20 vol ppm of the dry gas.

$$\frac{(109,032,000)(.00002)}{379 \text{ scf/mole}} = 5.754 \text{ moles/day/Train}$$

SO_2 = 64 lb/mole

$$\left(\frac{453.6 \text{ gm}}{\text{lb}}\right)\left(\frac{64 \text{ lb}}{\text{mole}}\right)\left(\frac{5.754 \text{ moles}}{\text{Day}}\right)\left(\frac{\text{Day}}{24 \text{ hr}}\right)\left(\frac{\text{hr}}{3600 \text{ sec}}\right) = \frac{1.933 \text{ gm/s}}{\text{Train}}$$

$$\frac{13.53 \text{ gm/s}}{7 \text{ Trn}}$$

EY 1/13/81

NO_x :

NO_x is 100 ppm Vol.

$\Rightarrow$ 10 903.2 scfd NO_x

@ NO_2 = 46 #/mole and 1 mole = 379 scf

$$\left(\frac{10\,903.2 \text{ scfd}}{379 \text{ moles/scf}}\right)\left(\frac{46 \text{ lb}}{\text{mole}}\right) = \underline{\underline{1323.3}} \text{ \#/Day}$$

$= \underline{\underline{0.66}}$ T/day/Train

$= \underline{\underline{4.62}}$ T/day/7 trains

Particulates :

Particulates are 0.06 grains/scf

1 lbm = 7000 grains

$$(146{,}000{,}000 \text{ scfd})\left(\frac{0.06 \text{ grains}}{\text{scf}}\right) = 8{,}760{,}000 \text{ grains/Day/Train}$$

@ 7000 grn/# = 1,251.4 #/Day/Train

= 8,760 #/Day/7 Trains

$= \underline{\underline{4.38}}$ T/day

CO : @ 0.1 Vol % $\Rightarrow$ 109,032 scf CO

$$\left(\frac{28 \text{ \#}}{\text{mole}}\right)\left(\frac{109032 \text{ scf}}{379 \text{ scf/mole}}\right) = 8{,}0556 \text{ \#/day}$$

= 4.03 T/day

= 42.3 gm/sec/train

= 296 gm/sec/7 Trains &f 1/13/

3.4 De Minimus Emissions

Particulate Emissions

Raw shale	1.65 g/sec	=	0.157 ton/day
Spent shale			
Lurgi	44.1 g/sec	=	4.20 ton/day
All others	20.4 g/sec	=	1.94 ton/day
Total spent shale			
	64.5 g/sec	=	6.14 ton/day
Total raw and spent			
	66.2 g/sec	=	6.30 ton/day

Mercury

Raw shale particulate emissions

$$0.157 \text{ ton/day} \times 0.18\times10^{-6} \times 100\% = 2.83\times10^{-8} \text{ ton/day}$$
$$= 5.65\times10^{-5} \text{ lb/day}$$
$$= 2.06\times10^{-2} \text{ lb/year}$$

Spent shale particulate emissions

$$6.14 \text{ ton/day} \times 0.18\times10^{-6} \times 30\% = 3.32\times10^{-7} \text{ ton/day}$$
$$= 6.63\times10^{-4} \text{ lb/day}$$
$$= 0.242 \text{ lb/year}$$

Condensed phase in off-gas (Lurgi)

$$6.76\times10^{4} \text{ ton/day} \times 0.18\times10^{-6} \times 70\% \times 0.001 = 8.52\times10^{-6} \text{ ton/day}$$
$$= 1.70\times10^{-2} \text{ lb/day}$$
$$= 6.22 \text{ lb/year}$$

Lead

Raw and spent shale particulate emissions

$$6.30 \text{ ton/day} \times 65\times10^{-6} = 4.10\times10^{-4} \text{ ton/day}$$
$$= 0.819 \text{ lb/day}$$
$$= 299 \text{ lb/year}$$

Fluorine

Raw and spent shale particulate emissions

$$6.30 \text{ ton/day} \times 3400\times10^{-6} = 2.14\times10^{-2} \text{ ton/day}$$
$$= 42.8 \text{ lb/day}$$
$$= 1.56\times10^{4} \text{ lb/year}$$

$$6.30 \text{ ton/day} \times 600\times10^{-6} = 3.78\times10^{-3} \text{ ton/day}$$
$$= 7.56 \text{ lb/day}$$
$$= 2.76\times10^{3} \text{ lb/year}$$

4.0

APPENDIX 4.0

Drawings

APPENDIX 4.0

DRAWINGS

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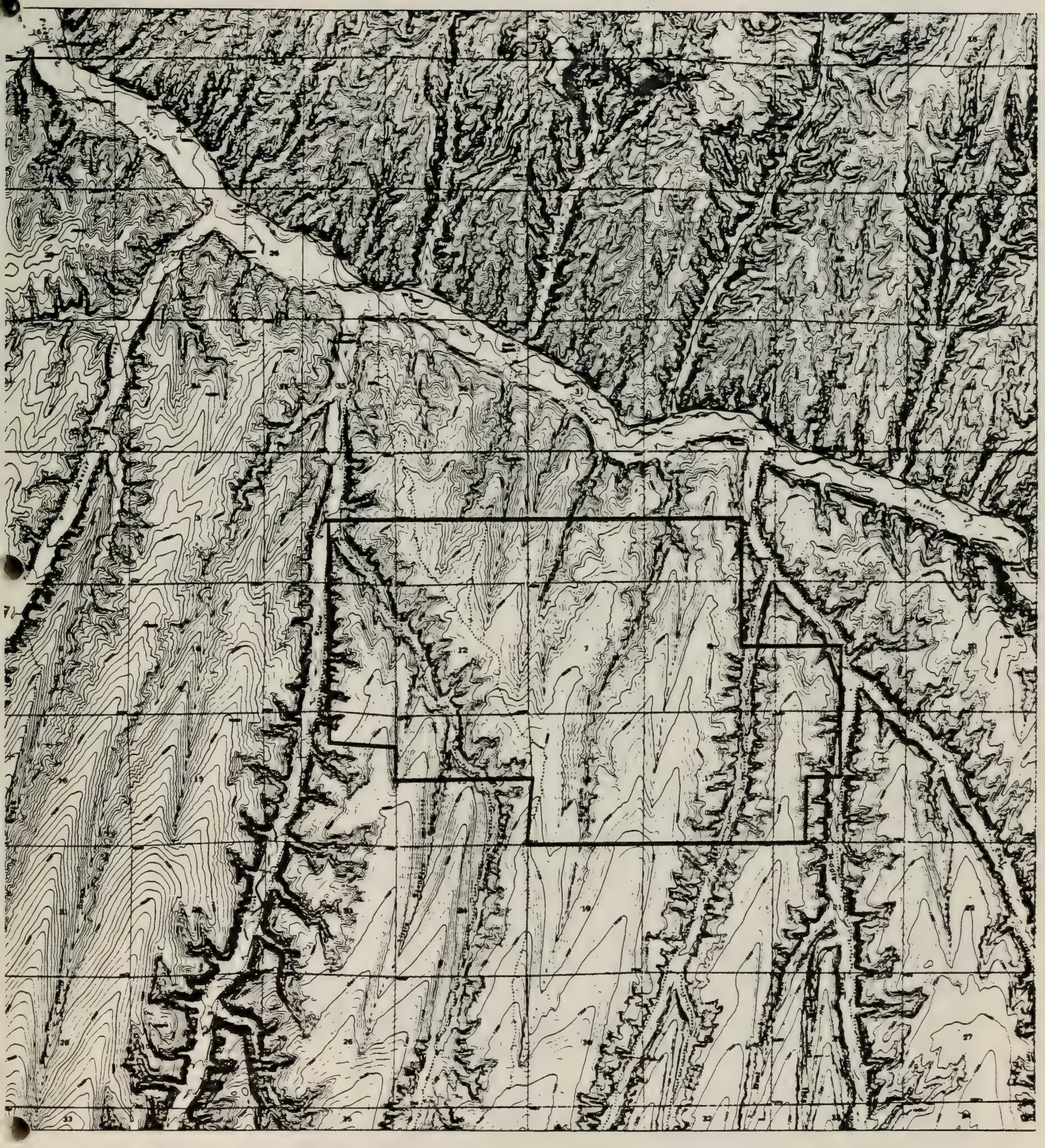
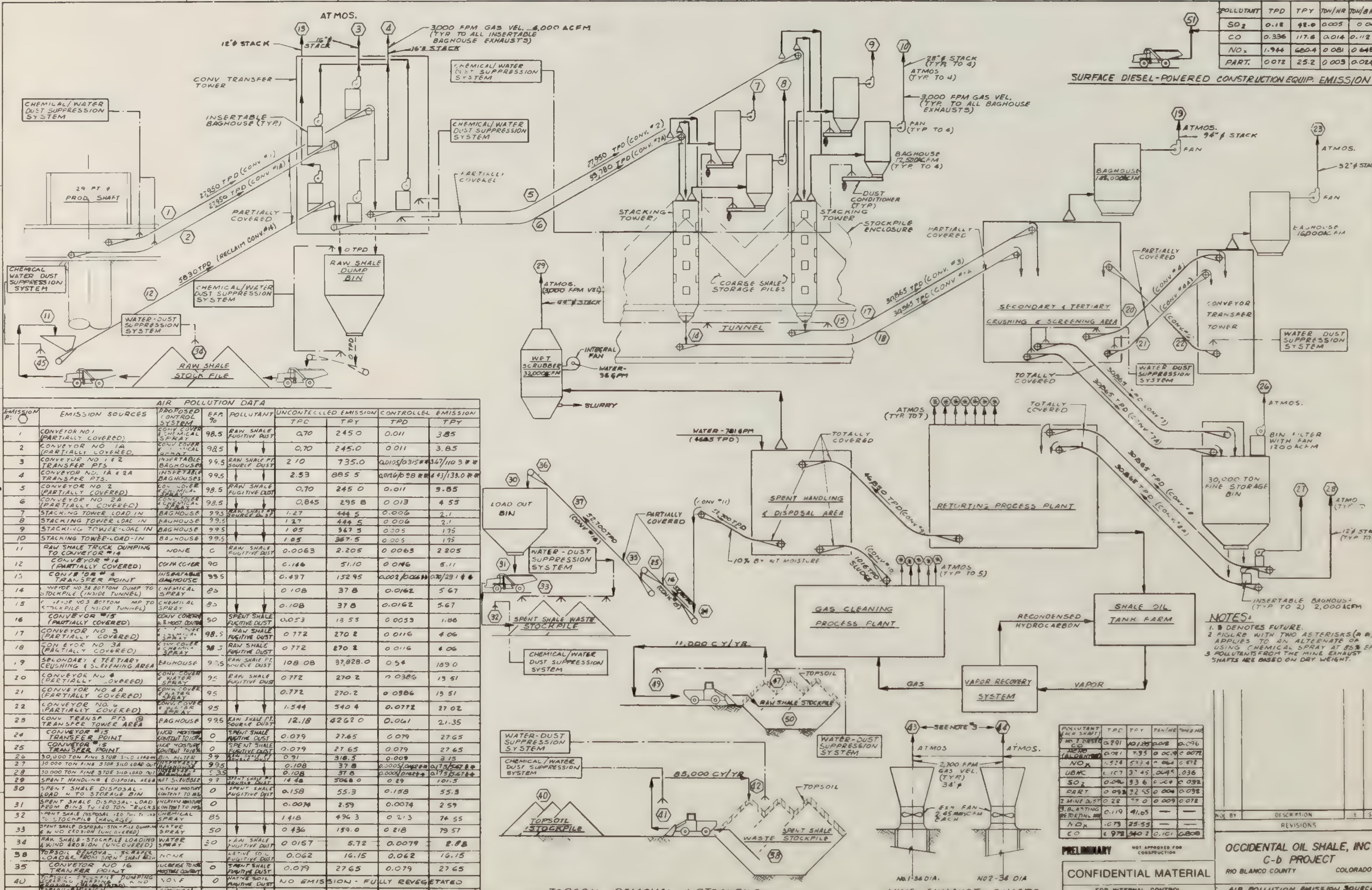


OXY DRAWING NO. I



SURFACE DIESEL-POWERED CONSTRUCTION EQUIP. EMISSION

POLLUTANT	TPD	TPY	TON/HR	TON/8 HR
SO_2	0.12	42.0	0.005	0.04
CO	0.336	117.6	0.014	0.112
NO_x	1.944	680.4	0.081	0.648
PART.	0.072	25.2	0.003	0.024

AIR POLLUTION DATA

EMISSION P: ⬡	EMISSION SOURCES	PROPOSED CONTROL SYSTEM	EFF. %	POLLUTANT	UNCONTROLLED EMISSION TPD	UNCONTROLLED EMISSION TPY	CONTROLLED EMISSION TPD	CONTROLLED EMISSION TPY
1	CONVEYOR NO 1 (PARTIALLY COVERED)	CONV COVER & CHEMICAL SPRAY	98.5	RAW SHALE FUGITIVE DUST	0.70	245.0	0.011	3.85
2	CONVEYOR NO 1A (PARTIALLY COVERED)	CONV COVER & CHEMICAL SPRAY	98.5	↓	0.70	245.0	0.011	3.85
3	CONVEYOR NO 1 & 2 TRANSFER PTS	INSERTABLE BAGHOUSES	99.5	RAW SHALE PT. SOURCE DUST	2.10	735.0	0.0105/0.315**	3.67/110.3**
4	CONVEYOR NO. 1A & 2A TRANSFER PTS.	INSERTABLE BAGHOUSES	99.5	↓	2.53	885.5	0.0126/0.38**	4.43/133.0**
5	CONVEYOR NO 2 (PARTIALLY COVERED)	CONV COVER & CHEMICAL SPRAY	98.5	RAW SHALE FUGITIVE DUST	0.70	245.0	0.011	3.85
6	CONVEYOR NO 2A (PARTIALLY COVERED)	CONV COVER & CHEMICAL SPRAY	98.5	↓	0.845	295.8	0.013	4.55
7	STACKING TOWER LOAD IN	BAGHOUSE	99.5	RAW SHALE PT. SOURCE DUST	1.27	444.5	0.006	2.1
8	STACKING TOWER LOAD IN	BAGHOUSE	99.5		1.27	444.5	0.006	2.1
9	STACKING TOWER-LOAD IN	BAGHOUSE	99.5		1.05	367.5	0.005	1.75
10	STACKING TOWER-LOAD-IN	BAGHOUSE	99.5	↓	1.05	367.5	0.005	1.75
11	RAW SHALE TRUCK DUMPING TO CONVEYOR #14	NONE	0	RAW SHALE FUGITIVE DUST	0.0063	2.205	0.0063	2.205
12	CONVEYOR #14 (PARTIALLY COVERED)	CONV COVER	90		0.146	51.10	0.0146	5.11
13	CONVEYOR #4 TRANSFER POINT	INSERTABLE BAGHOUSE	99.5		0.437	152.95	0.002/0.066**	0.70/23.1**
14	CONVEYOR NO 3A BOTTOM DUMP TO STOCKPILE (INSIDE TUNNEL)	CHEMICAL SPRAY	85		0.108	37.8	0.0162	5.67
15	CONVEYOR NO 3 BOTTOM DUMP TO STOCKPILE (INSIDE TUNNEL)	CHEMICAL SPRAY	85	↓	0.108	37.8	0.0162	5.67
16	CONVEYOR #15 (PARTIALLY COVERED)	CONV COVER & MOIST CONTROL	90	SPENT SHALE FUGITIVE DUST	0.053	18.55	0.0053	1.86
17	CONVEYOR NO 3 (PARTIALLY COVERED)	CONV COVER & CHEMICAL SPRAY	98.5	RAW SHALE FUGITIVE DUST	0.772	270.2	0.0116	4.06
18	CONVEYOR NO 3A (PARTIALLY COVERED)	CONV COVER & CHEMICAL SPRAY	98.5	RAW SHALE FUGITIVE DUST	0.772	270.2	0.0116	4.06
19	SECONDARY & TERTIARY CRUSHING & SCREENING AREA	BAGHOUSE	99.5	RAW SHALE PT. SOURCE DUST	108.08	37,828.0	0.54	189.0
20	CONVEYOR NO 4 (PARTIALLY COVERED)	CONV COVER & WATER SPRAY	95	RAW SHALE FUGITIVE DUST	0.772	270.2	0.0386	13.51
21	CONVEYOR NO 4A (PARTIALLY COVERED)	CONV COVER & WATER SPRAY	95		0.772	270.2	0.0386	13.51
22	CONVEYOR NO. 6 (PARTIALLY COVERED)	CONV. COVER & WATER SPRAY	95	↓	1.544	540.4	0.0772	27.02
23	CONV TRANSF PTS @ TRANSFER TOWER AREA	BAGHOUSE	99.5	RAW SHALE PT. SOURCE DUST	12.18	4262.0	0.061	21.35
24	CONVEYOR #15 TRANSFER POINT	INCR MOISTURE CONTENT TO 10%	0	SPENT SHALE FUGITIVE DUST	0.079	27.65	0.079	27.65
25	CONVEYOR #15 TRANSFER POINT	INCR MOISTURE CONTENT TO 10%	0	SPENT SHALE FUGITIVE DUST	0.079	27.65	0.079	27.65
26	30,000 TON FINE STOR SILO LOAD IN	BIN FILTER	99	RAW SHALE PT. SOURCE DUST	0.91	318.5	0.009	3.15
27	30,000 TON FINE STOR SILO LOAD OUT	INSERTABLE BAGHOUSE	99.5		0.108	37.8	0.0005/0.0162**	0.175/5.67**
28	30,000 TON FINE STOR SILO LOAD OUT	INSERTABLE BAGHOUSE	99.5	↓	0.108	37.8	0.0005/0.0162**	0.175/5.67**
29	SPENT HANDLING & DISPOSAL AREA	WET SCRUBBER	98	SPENT SHALE PT. SOURCE DUST	14.48	5068.0	0.29	101.5
30	SPENT SHALE DISPOSAL - LOAD IN TO STORAGE BIN	INCREASE MOISTURE CONTENT TO 10%	0	SPENT SHALE FUGITIVE DUST	0.158	55.3	0.158	55.3
31	SPENT SHALE DISPOSAL - LOAD FROM BINS TO 120 TON TRUCKS	INCREASE MOISTURE CONTENT TO 10%	0		0.0074	2.59	0.0074	2.59
32	SPENT SHALE DISPOSAL 120 TON TRUCKS TO STOCKPILE (HAULAGE)	CHEMICAL SPRAY	85		1.418	496.3	0.213	74.55
33	SPENT SHALE DISPOSAL-STOCKPILE DUMPING & WIND EROSION (UNCOVERED)	WATER SPRAY	50	↓	0.436	159.0	0.218	79.57
34	RAW SHALE-STOCKPILE LOADING & WIND EROSION (UNCOVERED)	WATER SPRAY	50	RAW SHALE FUGITIVE DUST	0.0157	5.72	0.0079	2.88
38	TOPSOIL REMOVAL - SCRAPER LOADER FROM SPENT SHALE [illegible]	NONE		NATIVE SOIL FUGITIVE DUST	0.062	16.15	0.062	16.15
35	CONVEYOR NO 16 TRANSFER POINT	INCREASE TO 10% MOISTURE CONTENT	0	SPENT SHALE FUGITIVE DUST	0.079	27.65	0.079	27.65
40	TOPSOIL - STOCKPILE DUMPING SCRAPING, SHAPING & WIND EROSION (REVEGETATED)	NONE	0	NATIVE SOIL FUGITIVE DUST	NO EMISSION - FULLY REVEGETATED			
41	TOPSOIL - EMISSION FROM VEHICULAR TRAFFIC OVER SPENT SHALE STOCKPILE	CHEMICAL SPRAY	85		0.0075	1.95	0.0011	0.385
42	TOPSOIL - DUMPING, SCRAPING, SHAPING, WIND EROSION (UNCOVERED) ON SPENT SHALE STOCKPILE	NONE	0	↓	0.05	13.0	0.05	13.0
45	RAW SHALE STOCKPILE TO CONVEYOR NO. 14 - VEHICULAR TRAFFIC	CHEMICAL SPRAY	85	RAW SHALE FUGITIVE DUST	0.019	6.65	0.0028	0.98
36	CONVEYOR NO. 16 TRANSFER POINT	INCREASE TO 10% MOISTURE CONTENT	0	SPENT SHALE FUGITIVE DUST	0.079	27.65	0.079	27.65
47	TOPSOIL REMOVAL - SCRAPER LOADER FROM RAW SHALE [illegible]	NONE	0	NATIVE SOIL FUGITIVE DUST	0.008	2.09	0.008	2.09
37	CONVEYOR NO. 16 (PARTIALLY COVERED)	CONV COVER & MOIST CONTROL	90	SPENT SHALE FUGITIVE DUST	0.053	18.55	0.053	1.86

TOPSOIL REMOVAL & STOCKPILE

49	TOPSOIL - EMISSION FROM VEHICULAR TRAFFIC OVER RAW SHALE STOCKPILE	WATER SPRAY	50	NATIVE SOIL FUGITIVE DUST	0.0003	0.078	0.00015	0.039
50	TOPSOIL - DUMPING, SCRAPING, SHAPING WIND EROSION FROM RAW SHALE STOCKPILE	NONE	0	↓	0.0064	1.67	0.0032	0.832

MINE EXHAUST SHAFTS

POLLUTANT (EACH SHAFT)	TPD	TPY	TON/HR	TON/8 HR
1. NO. 2 DIESEL CO	0.291	101.85	0.012	0.096
ALDEHYDES (ALDEHYDE)	0.021	7.35	0.0009	0.0072
NO_x	1.524	533.4	0.064	0.512
UBHC	0.107	37.45	.0045	.036
SO_2	0.096	33.6	0.004	0.032
PART	0.093	32.55	0.004	0.032
2. MINE DUST	0.28	77.0	0.009	0.072
3. BLASTING EXPLODING [illegible]	0.119	41.05	—	—
NO_x	.073	25.55	—	—
CO	0.972	340.2	0.101	0.808

NOTES:
1. ⬡ DENOTES FUTURE.
2. FIGURE WITH TWO ASTERISKS (**) APPLIES TO AN ALTERNATE OF USING CHEMICAL SPRAY AT 85% EFF.
3. POLLUTANTS FROM THE MINE EXHAUST SHAFTS ARE BASED ON DRY WEIGHT.

PRELIMINARY — NOT APPROVED FOR CONSTRUCTION

CONFIDENTIAL MATERIAL
FOR INTERNAL CONTROL
OFFICE ____
CONTRACT NO. ____
DRAWING NO ____
ISSUE NO. 3 DATE PRINTED 1/[illegible]/81

NO	BY	DESCRIPTION		

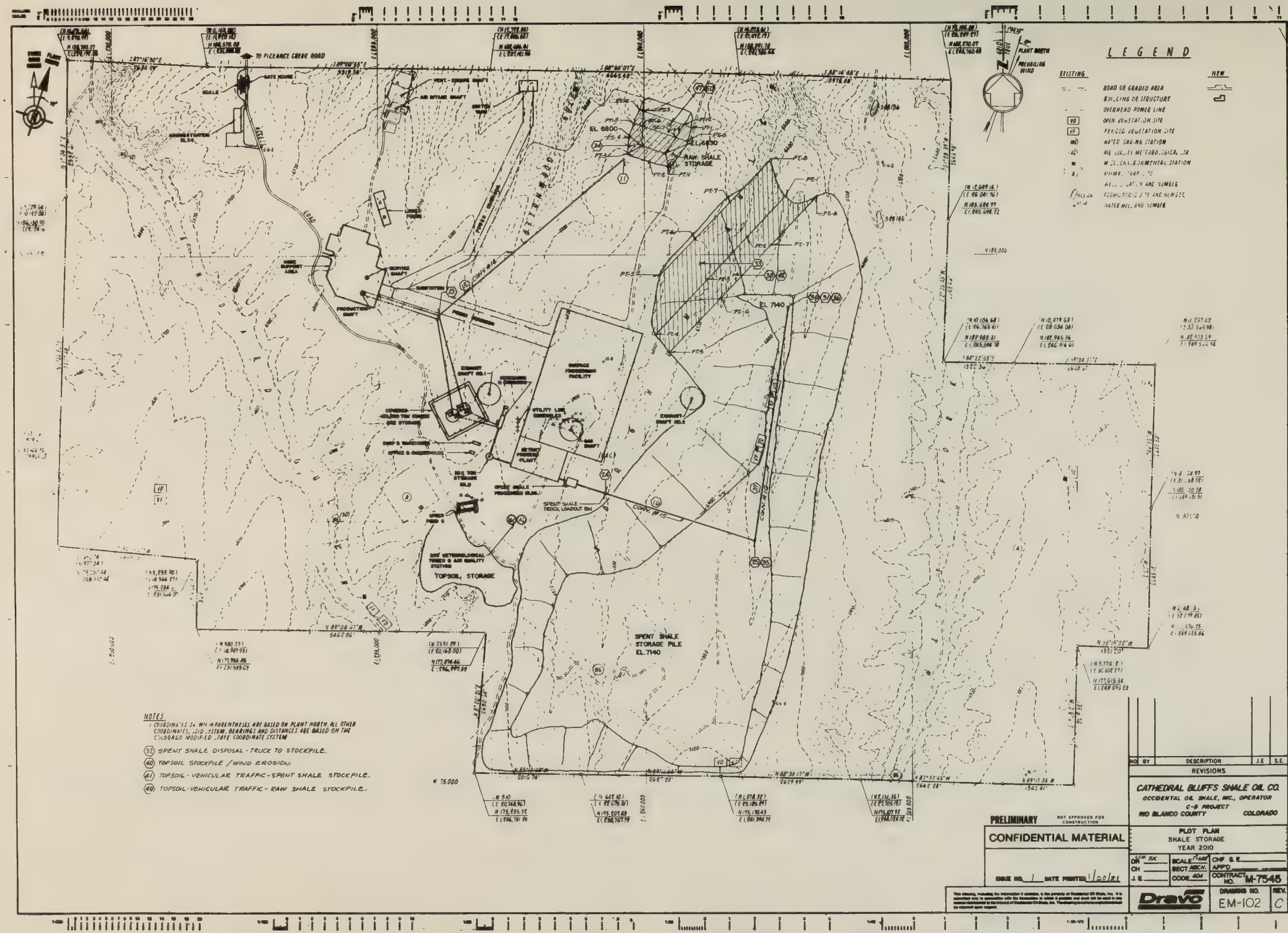
REVISIONS

OCCIDENTAL OIL SHALE, INC
C-b PROJECT
RIO BLANCO COUNTY COLORADO

AIR POLLUTION EMISSION SOURCES FLOW SHEET
PSD PERMIT APPLICATION
113,875 BPD SHALE OIL

DR [illegible] SCALE N/A CHF S.E. ____
CH [illegible] SECT [illegible] APP'D ____
J.E. ____ CODE 415 CONTRACT NO M 7541

Dravo
DRAWING NO EM-101 REV. D


LEGEND
EXISTING
NEW
ROAD OR GRADED AREA
BUILDING OR STRUCTURE
OVERHEAD POWER LINE
OPEN VEGETATION SITE
FENCED VEGETATION SITE
WATER GAGING STATION
PLANT NORTH
PREVAILING WIND
TO PICEANCE CREEK ROAD
GATE HOUSE
SCALE
ADMINISTRATION BLDG.
AIR INTAKE SHAFT
ROAD
SERVICE SHAFT
PRODUCTION SHAFT
EL 6800
RAW SHALE STORAGE
EL 7140
EXHAUST SHAFT NO. 1
EXHAUST SHAFT NO. 2
SURFACE PROCESSING FACILITY
UTILITY LINE CORRIDOR
SPENT SHALE TRUCK LOADOUT BIN
SPENT SHALE PROCESSING BLDG.
TOPSOIL STORAGE
SPENT SHALE STORAGE PILE EL 7140
CONV. #15
CONV. #16
NOTES
1. COORDINATES SHOWN IN PARENTHESES ARE BASED ON PLANT NORTH, ALL OTHER COORDINATES, GRID SYSTEM, BEARINGS AND DISTANCES ARE BASED ON THE COLORADO MODIFIED STATE COORDINATE SYSTEM
(32) SPENT SHALE DISPOSAL - TRUCK TO STOCKPILE.
(40) TOPSOIL STOCKPILE / WIND EROSION.
(41) TOPSOIL - VEHICULAR TRAFFIC - SPENT SHALE STOCKPILE.
(49) TOPSOIL - VEHICULAR TRAFFIC - RAW SHALE STOCKPILE.
NO. BY DESCRIPTION J.E. S.E.
REVISIONS
CATHEDRAL BLUFFS SHALE OIL CO.
OCCIDENTAL OIL SHALE, INC., OPERATOR
C-B PROJECT
RIO BLANCO COUNTY COLORADO
PLOT PLAN
SHALE STORAGE
YEAR 2010
PRELIMINARY
NOT APPROVED FOR CONSTRUCTION
CONFIDENTIAL MATERIAL
ISSUE NO. 1 DATE PRINTED 1/20/81
CONTRACT NO. M-7545
Dravo
DRAWING NO. EM-102
REV. C

NO	BY	DESCRIPTION	J E	S E
C		ADDED EMISSION POINTS		
B		RELOCATED RETORT PROCESS PLT & EMISSION PTS		
A	DEB	REVISED EMISSION POINTS		

REVISIONS

OCCIDENTAL OIL SHALE, INC.
C-b
RIO BLANCO COUNTY COLORADO

GENERAL ARRANGEMENT
PLOT PLAN
ENLARGED PROCESS AREA

PRELIMINARY NOT APPROVED FOR CONSTRUCTION

CONFIDENTIAL MATERIAL

ISSUE NO 3 DATE PRINTED 1/20/81

DR DEM | SCALE 1"=200' | CHF S E
CH | SECT MECH | APP D
J E | CODE 404 | CONTRACT NO M7541

Dravo

DRAWING NO EM-103 REV C

EMISSION POINT GEOMETRY					EMISSIONS (gm/sec)							STACK CHARACTERISTICS				
EMISSION POINT	SOURCE	GEOMETRIC TYPE	COORDINATES	ELEVATION	24 HR. SO_2	ANN SO_2	24 HR. TSP	ANN TSP	1 HR. CO	8 HR CO	NOX	HGT (M)	DIAM. (M)	EXIT TEMP(K)	VOL. FLOW(m³/s)	EXIT SPEED(m/s)
1	CONVEYOR NO 1 (PARTIALLY COVERED)	LINE, 1500 FT	LOW PT. N 184,276.95; E 1,234,695.69 HIGH PT. N 183,818.42; E 1,236,122.27	LOW PT. EL. 6828'-0 HIGH PT. EL. 6942'-0			0.11	0.11								
2	CONVEYOR NO 1A (PARTIALLY COVERED)	LINE, 1500 FT	LOW PT. N 184,335.91; E 1,234,714.85 HIGH PT. N 183,872.38; E 1,236,141.43	LOW PT. EL. 6828'-0 HIGH PT. EL. 6942'-0			0.11	0.11								
3	CONVEYOR NO 1 & 1A TRANSFER POINTS	POINT	N 183,813.42; E 1,236,122.27	EL. 6945'-0			0.13	0.13				2	0.41			
4	CONVEYOR NO 2 & 2A TRANSFER POINTS	POINT	N 183,872.38; E 1,236,141.43	EL. 6945'-0			0.13	0.13				2	0.41			
5	CONVEYOR NO 2 (PARTIALLY COVERED)	LINE, 1837.78 FT	LOW PT. N 183,813.42; E 1,236,122.27 HIGH PT. N 181,998.16; E 1,236,405.23	LOW PT. EL. 6917'-0 HIGH PT. EL. 6967'-0			0.12	0.12								
6	CONVEYOR NO 2A (PARTIALLY COVERED)	LINE, 1831.88 FT	LOW PT. N 183,872.38; E 1,236,141.43 HIGH PT. N 182,100.38; E 1,236,605.67	LOW PT. EL. 6917'-0 HIGH PT. EL. 6967'-0			0.15	0.15								
7	STACKING TOWER-LOAD-IN	POINT	N 182,100.30; E 1,236,605.67	EL. 6957'-0			0.07	0.07				15	0.71			
8	STACKING TOWER-LOAD-IN	POINT	N 182,100.30; E 1,236,605.67	EL. 6957'-0			0.07	0.07				15	0.71			
9	STACKING TOWER-LOAD-IN	POINT	N 181,998.16; E 1,236,405.23	EL. 6957'-0			0.06	0.06				15	0.71			
10	STACKING TOWER-LOAD-IN	POINT	N 181,998.16; E 1,236,405.23	EL. 6957'-0			0.06	0.06				15	0.71			
11	RAW SHALE TRUCK DUMPING TO CONVEYOR NO. 14	POINT	N 186,780; E 1,239,620	EL 6830'-0			0.07 (4)	0.07 (4)								
12	CONVEYOR NO 14 (PARTIALLY COVERED)	LINE, 4600 FT.	LOW PT N 181,998.16, E 1,239,620 HIGH PT. N 183,872.38; E 1,236,141.43	EL 6830'-0 EL. 6945'-0			0.18 (4)	0.18 (4)								
13	CONVEYOR NO. 14 TRANSFER POINT	POINT	N 183,872.38, E 1,236,141.43	EL. 6945'-0			0.02	0.02				2	0.30			
14	CONVEYOR NO 3 BOTTOM DUMP TO STOCKPILE (INSIDE TUNNEL)	POINT	N 182,100.30; E 1,236,605.67	EL. 6836'-0			0.17	0.17								
15	CONVEYOR NO 3A BOTTOM DUMP TO STOCKPILE (INSIDE TUNNEL)	POINT	N 181,998.16; E 1,236,405.23	EL. 6836'-0			0.17	0.17								
16	CONVEYOR NO 15 (PARTIALLY COVERED)	LINE, 2,950 FT.	LOW PT. N 180,525; E 1,239,240 HIGH PT. N 179,600, E 1,237,950	EL. 6810'-0 EL. 7,140-0			0.05 (4)	0.05 (4)								
17	CONVEYOR NO 3 (PARTIALLY COVERED)	LINE 857.23 FT	LOW PT. N 181,998.16; E 1,236,405.23 HIGH PT. N 181,804.89; E 1,237,240.39	LOW PT. EL. 6836'-0 HIGH PT. EL. 6977'-0			0.12	0.12								
18	CONVEYOR NO 3A (PARTIALLY COVERED)	LINE 698.1 FT	LOW PT. N 182,100.30; E 1,236,605.67 HIGH PT. N 181,822.05; E 1,237,245.92	LOW PT. EL. 6836'-0 HIGH PT. EL. 6977'-0			0.12	0.12								
19	SECONDARY AND TERTIARY CRUSHING & SCREENING AREA	POINT	N 181,912.50; E 1,237,250.00	EL. 7000'-0			5.68	5.43				25.0	2.67	288.0	85.9	15.0
20	CONVEYOR NO 4 (PARTIALLY COVERED)	LINE 164.0 FT	LOW PT. N 181,968.75; E 1,237,362.50 HIGH PT. N 182,118.75; E 1,237,400.00	LOW PT. EL. 6900'-0 HIGH PT. EL. 6962'-6			0.40	0.40								
21	CONVEYOR NO 4A (PARTIALLY COVERED)	LINE 164.0 FT	LOW PT. N 181,987.50; E 1,237,325.00 HIGH PT. N 182,137.50; E 1,237,362.50	LOW PT. EL. 6900'-0 HIGH PT. EL. 6962'-6			0.41	0.41								
22	CONVEYOR NO 6 (PARTIALLY COVERED)	LINE 164.0 FT	LOW PT. N 182,137.50; E 1,237,362.50 HIGH PT. N 181,987.50; E 1,237,325.00	LOW PT. EL. 6919'-0 HIGH PT. EL. 6973'-6			0.81	0.81								
23	CONVEYOR TRANSFER POINTS @ TRANSFER TOWER AREA	POINT	N 182,193.75; E 1,237,381.25	EL. 6980'-0			0.64	0.61				23.0	1.0	288.0	14.2	15.0
26	30,000 TON FINE STORAGE SILO-LOAD-IN	POINT	N 181,182.50; E 1,236,935.06	EL 7060'-0			0.09	0.09				20.0	1.0			
27	30,000 TON FINE STORAGE SILO LOAD OUT	POINT	N 181,220.00; E 1,237,075.00	EL. 6908'-0			0.006	0.006				20.0	1.0			
28	30,000 TON FINE STORAGE SILO LOAD-OUT	POINT	N 181,220.00; E 1,237,075.00	EL 6908'-0			0.006	0.006				20.0	1.0			
29	SPENT HANDLING & DISPOSAL AREA	POINT	N 180,730.0; E 1,238,615.00	EL 7016'-0			3.05	2.91				10.0	1.1	288.0	15.0	15.0
30	SPENT SHALE DISPOSAL LOAD IN TO STORAGE BIN	POINT	N 180,618.57, E 1,238,131.25	EL 7140'-0			1.66	1.66								
31	SPENT SHALE DISPOSAL LOAD FROM BINS TO 120 TON TRUCKS	POINT	N 180,618.75; E 1,238,131.25	EL 7140'-0			0.08	0.08								
32	SPENT SHALE DISPOSAL 120 TON TRUCKS TO STOCKPILE (HAULAGE)	LINE 9850 FT	PT 1-N PT 2-N	EL EL			3.17 (4)	1.92 (4)								
33	SPENT SHALE DISPOSAL STOCKPILE DUMPING SCRAPING & SHAPING WIND EROSION (UNCOVERED)	AREA 50 ACRES	PT1 N 186,090.0; E 1,242,660.0 PT2 N 185,500.0; E 1,241,920.0 PT3 N 184,510.0; E 1,241,170.0 PT4 N 183,470.0; E 1,240,210.0 PT5 N 184,620.0; E 1,240,280.0 PT6 N 185,290.0; E 1,240,940.0 PT7 N 185,960.0; E 1,241,590.0 PT8 N 186,740.0; E 1,242,350.0	EL 6680-0 EL 6910-0 EL 6970-0 EL 6800-0 EL 6800-0 EL 6700-0 EL 6680-0 EL 6520-0			15.6 (4)	1.00 (4)								
34	RAW SHALE-STOCKPILE DUMPING-SCRAPING & SHAPING WIND EROSION (UNCOVERED)	AREA 15 ACRES	PT1 N 186,650.0; E 1,240,450.0 PT2 N 186,750.0; E 1,240,030.0 PT3 N 186,870.0; E 1,239,630.0 PT4 N 187,300.0; E 1,239,700.0 PT5 N 187,460.0; E 1,239,780.0 PT6 N 187,390.0; E 1,239,950.0 PT7 N 187,200.0; E 1,240,540.0 PT8 N 187,110.0; E 1,240,790.0	EL 6750-0 EL 6720-0 EL 6700-0 EL 6660-0 EL 6660-0 EL 6760-0 EL 6630-0 EL 6750-0			0.56 (4)	0.04 (4)								
35	CONVEYOR NO. 16 TRANSFER POINT	POINT	N 179,600, E 1,237,950	EL 7140-0			0.83 (4)	0.83 (4)								
36	CONVEYOR NO 16 TRANSFER POINT	POINT	N 180,618.75; E 1,238,131.25	EL 7140-0			0.83 (4)	0.83 (4)								
37	CONVEYOR NO. 16 (PARTIALLY COVERED)	LINE 4,650 FT	LOW PT N 179,600; E 1,237,950 HIGH PT N 180,618.57; E 1,238,131.25	EL 7140-0 EL 7140-0			0.05 (4)	0.05 (4)								
38	TOPSOIL REMOVAL-SCRAPER/LOADER FROM SPENT SHALE AREA	RECTANGLE (35 ACRES)	PT1 N 186,030.0; E 1,242,660.0 PT2 N 185,500.0; E 1,241,920.0 PT3 N 184,510.0; E 1,241,170.0 PT4 N 183,470.0; E 1,240,210.0 PT5 N 184,600.0; E 1,240,470.0 PT6 N 184,800.0; E 1,241,450.0 PT7 N 185,500.0; E 1,242,370.0 PT8 N 186,100.0; E 1,243,280.0	EL 6680-0 EL 6670-0 EL 6700-0 EL 6800-0 EL 6800-0 EL 6860-0 EL 6630-0 EL 6680-0			0.46 (4)	0.46 (4)								
40	TOPSOIL-STOCKPILE DUMPING & WIND EROSION (REVEGETATED)	RECTANGLE (35 ACRES)	NOT APPLICABLE	(FULLY REVEGETATED)			0	0								
41	TOPSOIL-EMISSION FROM VEHICULAR TRAFFIC OVER SPENT SHALE STOCKPILE	LINE 4200 FT.	PT1 N 180,618.57; E 1,238,131.25 PT2 N 186,740.0; E 1,242,350.0	EL 7140-0 EL 6520-0			0.02 (4)	0.01 (4)								
42	TOPSOIL-DUMPING, SCRAPING, SHAPING WIND EROSION (UNCOVERED) ON SPENT SHALE STOCKPILE	RECTANGLE (35 ACRES)	PT1 N 186,030.0; E 1,242,660.0 PT2 N 185,500.0; E 1,241,920.0 PT3 N 184,510.0; E 1,241,170.0 PT4 N 183,470.0; E 1,240,210.0 PT5 N 184,600.0; E 1,240,470.0 PT6 N 184,800.0; E 1,241,650.0 PT7 N 185,500.0; E 1,242,370.0 PT8 N 186,100.0; E 1,243,250.0	EL 6680-0 EL 6910-0 EL 6970-0 EL 6800-0 EL 6800-0 EL 6700-0 EL 6680-0 EL 6520-0												
43	MINE EXHAUST SHAFT NO 1	POINT	N 182,382.24; E 1,237,074.76	EL 6920-0	1.01	1.01	4.53	4.34	30.01	13.81	16.8	30.0	10.4	294.0	1623	19.1
44	MINE EXHAUST SHAFT NO 2	POINT	N 181,239.78; E 1,240,833.86	EL 6720-0	1.01	1.01	4.53	4.34	30.01	13.81	16.8	30.0	10.4	294.0	1623	19.1
45	RAW SHALE STOCKPILE TO COARSE SHALE STOCKPILE VEHICULAR TRAFFIC	LINE 1200 FT.	PT1 N 186,780.0; E 1,239,620.0 PT2 N 187,100.0; E 1,240,790.0	EL 6830-0 EL 6750-0												
24	CONVEYOR NO 15 TRANSFER POINT	POINT	N 180,525; E 1,239,240	EL. 6810'-0												
25	CONVEYOR NO. 15 TRANSFER POINT	POINT	N 179,600; E 1,237,950	EL 7140'-0												

NOTE: SEE NOTES (1) THRU (4) ON DRAWING EM-105.

PRELIMINARY

NOT APPROVED FOR CONSTRUCTION

NO	BY	DESCRIPTION	J E	S E

REVISIONS

CONFIDENTIAL MATERIAL

FOR INTERNAL CONTROL

OFFICE

CONTRACT NO

DRAWING NO

ISSUE NO 3 DATE PRINTED 11/20/81

OCCIDENTAL OIL SHALE, INC.
C-b PROJECT
RIO BLANCO COUNTY COLORADO

AIR POLLUTION EMISSION SOURCES TABULATION SHEET

DR W05M-0 SCALE N/A CHF S E
CH [signature] SECT MECH APP D
J E CODE 4/9 CONTRACT NO M-7541

Dravo DRAWING NO EM-104 REV E

EMISSION POINT GEOMETRY					EMISSIONS (gm/sec)							STACK CHARACTERISTICS				
EMISSION POINT	SOURCE	GEOMETRIC TYPE	COORDINATES	ELEVATION	24HR SO_2	ANN SO_2	24HR TSP	ANN TSP	1HR CO	8HR CO	NOX	HGT (M)	DIAM (M)	EXIT TEMP(K)	VOL FLOW(m^3/s)	EXIT SPEED(m/s)
47	TOP SOIL - DUMPING SCRAPING, SHAPING, WIND EROSION UNCOVERED) ON RAW SHALE STOCKPILE	RECTANGLE (5 ACRES)	PT1 N 187,380.0, E 1,240,880.0 PT2 N 187,430.0, E 1,241,740.0 PT3 N 187,690.0, E 1,239,998.0 PT4 N 182,299.0, E 1,239,992.0 PT5 N 187,460.0, E 1,239,780.0 PT6 N 187,390.0, E 1,239,950.0 PT7 N 187,200.0, E 1,240,540.0 PT8 N 187,110.0, E 1,240,790.0	EL 6740.0 EL 6774.0 EL 6702.0 EL 6670.0 EL 6660.0 EL 6760.0 EL 6830.0 EL 6750.0			0.084(4)	0.084(4)								
49	TOPSOIL - EMISSION FROM VEHICULAR TRAFFIC TO RAW SHALE STOCKPILE	LINE 1200 FT	PT1 N 186,780.0, E 1,239,620.0 PT2 N 187,110.0, E 1,240,790.0	EL 6830.0 EL 6750.0			0.002(4)	0.002(4)								
50	TOPSOIL REMOVAL - SCRAPER/LOADER FROM RAW SHALE AREA	RECTANGLE (5 ACRES)	PT1 N 187,380.0, E 1,240,880.0 PT2 N 187,430.0, E 1,241,740.0 PT3 N 187,690.0, E 1,239,998.0 PT4 N 182,299.0, E 1,239,992.0 PT5 N 187,460.0, E 1,239,780.0 PT6 N 187,390.0, E 1,239,950.0 PT7 N 187,200.0, E 1,240,540.0 PT8 N 187,100.0, E 1,240,790.0	EL 6740.0 EL 6735.0 EL 6700.0 EL 6700.0 EL 6660.0 EL 6710.0 EL 6760.0 EL 6750.0			0.033(4)	0.033(4)								
51	SURF GAS & DIESEL-POWERED CONSTR. EQUIPMENT EMISSION	NOT	APPLICABLE													
52	MIS FGD PROCESS STACK No 1	POINT	N 182,180 E 1,238,280	EL 6850.0	44.0	44.0	1.69	1.69	0	0	17.65	34.0	4.71	346	637	36.6
53	No 2	POINT	N 182,110 E 1,238,480	EL 6850.0	44.0	44.0	1.69	1.69	0	0	17.65	34.0	4.71	346	637	36.6
54	No 3	POINT	N 182,040 E 1,238,700	EL 6850.0	44.0	44.0	1.69	1.69	0	0	17.65	34.0	4.71	346	637	36.6
55	No 4	POINT	N 181,960 E 1,238,920	EL 6950.0	44.0	44.0	1.69	1.69	0	0	17.65	34.0	4.71	346	637	36.6
56	No 5	POINT	N 181,900 E 1,329,120	EL 6850.0	44.0	44.0	1.69	1.69	0	0	17.65	34.0	4.71	346	637	36.6
57																
58	11 TEMP POWER GENERATORS	POINT	N 185,200 E 1,234,100	EL 6828.0	0.010	0	0	0	6.2	6.2	1.3	.61	0.85	845.0	.130	200.0
59	CEMENT BATCH PLANT	POINT	N 186,300 E 1,234,700	EL 6828.0	0	0	0.05	0.05	0	0	0	5.5	0.34	288.0	1.24	
60	CEMENT BATCH PLANT BOILER	POINT	N 184,300 E 1,234,700	EL 6828.0	0.260	0.130	0.06	0.03	0.03	0.03	0.035	5.5	0.51	589.0	3.21	15.7
—	GAS CLEANING PROCESS PLANT	RECTANGLE	W CORNER N 184,010.00, E 1,238,450.00 S CORNER N 181,580.00, E 1,237,650.00 N CORNER N 183,530.00, E 1,239,960.00 E CORNER N 181,090.00, E 1,239,170.00	EL 6900.0 EL 6900.0 EL 6900.0 EL 6900.0												
—	RETORT PROCESS PLANT	RECTANGLE	N CORNER N 181,320, E 1,238,550 W CORNER N 181,580, E 1,237,650 E CORNER N 180,740, E 1,238,370 S CORNER N 181,020, E 1,237,470	EL 6900.0 EL 6900.0 EL 6900.0 EL 6900.0												
61	LURGI STACKS 1 & 5	POINT	N 181,300 E 1,237,630	EL 6890.0	3.87	3.87	13.2	13.2	84.6	84.6	13.86	30.0		433.0	1897(3)	36.6
62	LURGI STACKS 2, 3(1) 6, & 7	POINT	N 181,180 E 1,237,980	EL 6895.0	5.80	5.80	19.8	19.8	126.9	126.9	20.79	30.0		433.0	2845(2)	36.6
63	LURGI STACKS 4, 8	POINT	N 181,080 E 1,238,250	EL 6900.0	3.87	3.87	13.2	13.2	84.6	84.6	13.86	30.0		433.0	1897(3)	36.6

NOTES (1) STACK EMISSIONS FOR STACK #3 NOT COUNTED SINCE ONLY 7 OF 8 LURGIS OPERATE SIMULTANEOUSLY
(2) 2 LURGI STACKS
(3) 3 LURGI STACKS
(4) YEAR 25

NO	BY	DESCRIPTION	JE	SE

REVISIONS

PRELIMINARY NOT APPROVED FOR CONSTRUCTION

CONFIDENTIAL MATERIAL

ISSUE NO. 2 DATE PRINTED 1/20/81

CATHEDRAL BLUFFS SHALE OIL CO
OCCIDENTAL OIL SHALE INC OPERATOR
C-B PROJECT
RIO BLANCO COUNTY COLORADO

AIR POLLUTION EMISSION SOURCES TABULATION SHEET

DR CCB 5-1-80 CH ___ JE ___ | SCALE N/A SECT MECH CODE 4-9 | CHF S E ___ APP'D ___ | CONTRACT NO M-7541

Dravo | DRAWING NO EM-105 | REV E

AIR POLLUTION D/[illegible]R NON-DUST POINT SOURCES

Emission Pt. ○	Emission Sources	Proposed Control System	Efficiency %	Pollutant	Emissions w/o Controls TPD	Emissions w/o Controls TPY	Emissions with Controls TPD	Emissions with Controls TPY
43	Mine Exhaust Shaft #1	None	0	SO_2	0.096	35.0	0.096	35.0
		None	0	TSP	0.431	151.0	0.431	151.0
		None	0	NOX	1.60	584.0	1.60	584.0
		None	0	CO**	2.86	1,043.0	2.86	1,043.0
44	Mine Exhaust Shaft #2	None	0	SO_2	0.096	35.0	0.096	35.0
		None	0	TSP	0.431	151.0	0.431	151.0
		None	0	NOX	1.60	584.0	1.60	584.0
		None	0	CO**	2.86	1,043.0	2.86	1,043.0
52	FGD Stack #1	Flue gas desulfurization	95	SO_2	83.8	30,600	4.19	1,530
		Wet scrubber	100% except gas gen TSP	TSP			0.161	58.7
		Low NOX burner	89.3	NOX	1,551.0	5.67×10^4	16.6	6,070
		Incineration	100	CO			0	0
53	FGD Stack #2	same as source 52						
54	FGD Stack #3	" " " "						
55	FGD Stack #4	" " " "						
56	FGD Stack #5	" " " "						
58	Eleven temp power generators	None	0	SO_2	0.001	0.348	0.001	0.348
		--	--	TSP		0		0
		None	0	NOX	0.124	45.2	0.124	45.2
		None	0	CO	0.590	216.0	0.590	216.0
59	Cement batch plant	--	--	SO_2	0		0	
		Baghouse	99	TSP	0.476	174.0	0.005	1.74
		--	--	NOX	0	0	0	0
		--	--	CO	0	0	0	0
60	Cement batch plant boiler	None	0	SO_2	0.025	9.04	0.025	9.04
		None	0	TSP	0.006	1.04	0.006	1.04
		None	0	NOX	0.003	1.22	0.003	1.22
		None	0	CO	0.003	1.04	0.003	1.04
61	Lurgi stacks #1 & #5	None, except scrubbed in liftpipe	0	SO_2	0.369	135.0	0.369	135.0
		Electrost. ppt.	99.9	TSP	1.26×10^3	4.59×10^5	1.26	459.0
		None	0	NOX	1.32	482.0	1.32	482.0
		None	0	CO	8.06	2,940.0	8.06	2,940.0
62	Lurgi stacks #2*, #6 and #7	None, except scrubbed in liftpipe	0	SO_2	0.552	202.0	0.552	202.0
		Electrost. ppt.	99.9	TSP	1.89×10^3	6.88×10^5	1.89	688.0
		None	0	NOX	1.98	723.0	1.98	723.0
		None	0	CO	12.1	4,410.0	12.1	4,410.0
63	Lurgi stacks #4 & #8	same as source 61						
Total Emissions from this Table:				SO_2	421.0	1,530,600.0	22.5	8,201.0
				TSP	4,411.0	1,606,500.0	6.1	2,204.0
				NOX	7,763.0	59,600.0	90.9	32,651.0
				CO	34.5	12,593.0	34.5	12,593.0
Total Emissions from Table EM101:				TSP	156.0	54,600.0	2.3	791.0
Grand Total Emissions:				SO_2	421.0	1,530,600.0	22.5	8,201.0
				TSP	4,567.0	1,661,100.0	8.4	2,995.0
				NOX	7,763.0	59,600.0	90.9	32,651.0
				CO	34.5	12,593.0	34.5	12,593.0

* In the modeling, 7 of 8 Lurgi's operate at once; #3 is assumed to be inoperative.

** Based on highest 1-hour.

OXY DRAWING NO. 2

NO	BY	DESCRIPTION	J E	S E
B		REVISED EMISSION POINTS		
A				

REVISIONS

OCCIDENTAL OIL SHALE, INC.
C-b
RIO BLANCO COUNTY COLORADO

PRELIMINARY NOT APPROVED FOR CONSTRUCTION

CONFIDENTIAL MATERIAL

GENERAL ARRANGEMENT
PLOT PLAN
ENLARGED PROCESS AREA

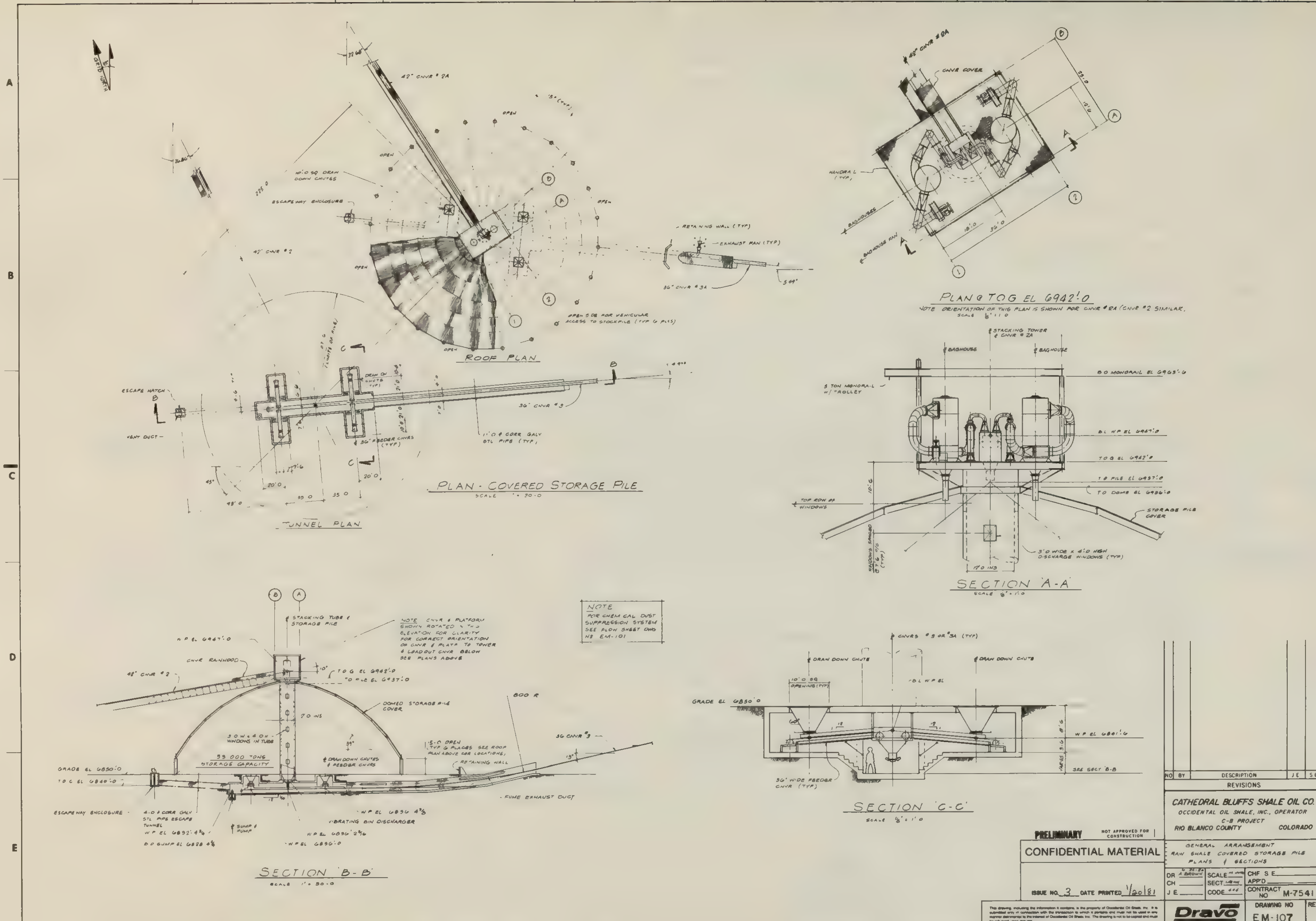
DR | SCALE | CHF S E
CH | SECT | APP'D
J E | CODE | CONTRACT NO M7541

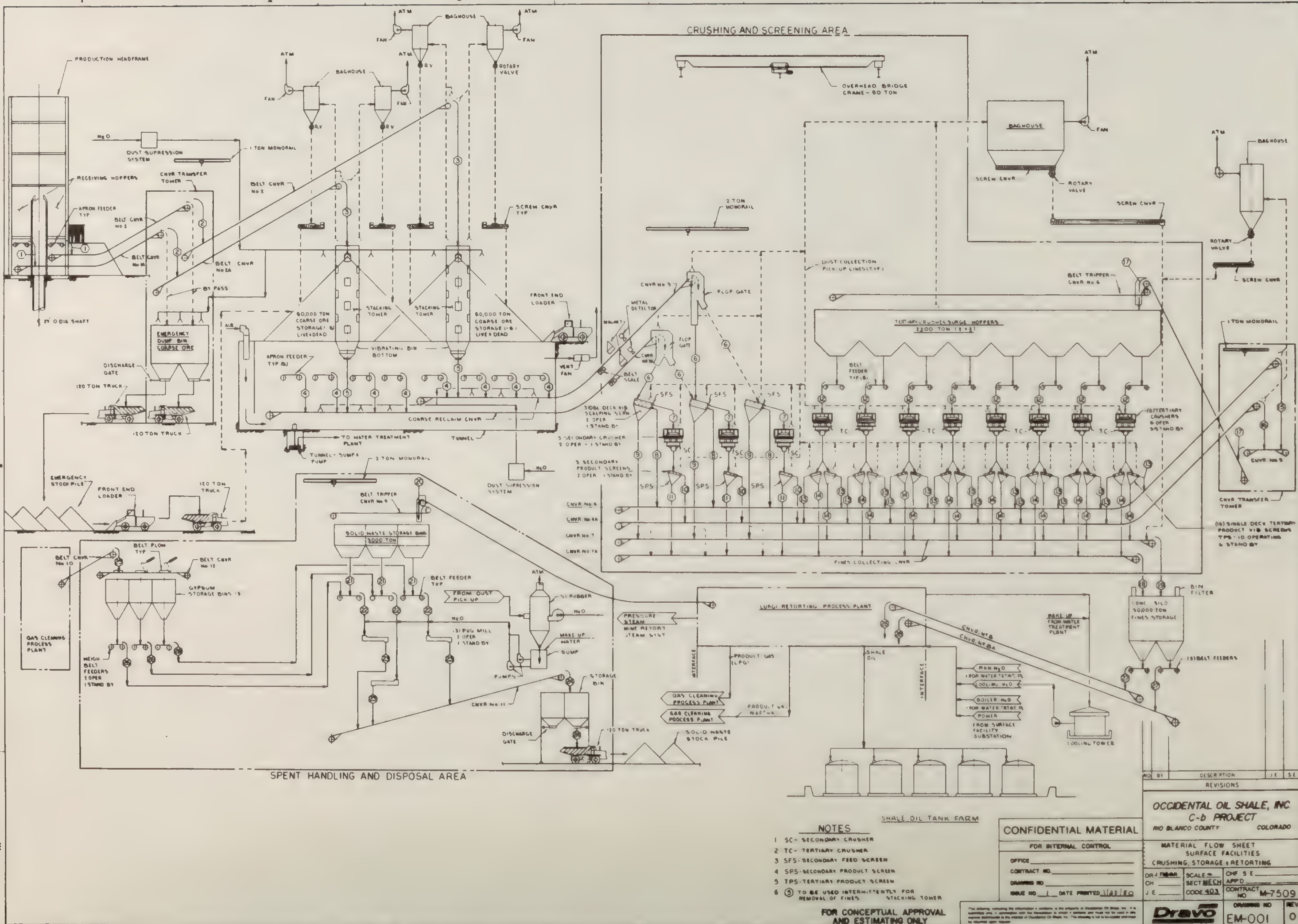
ISSUE NO 1 DATE PRINTED /20/81

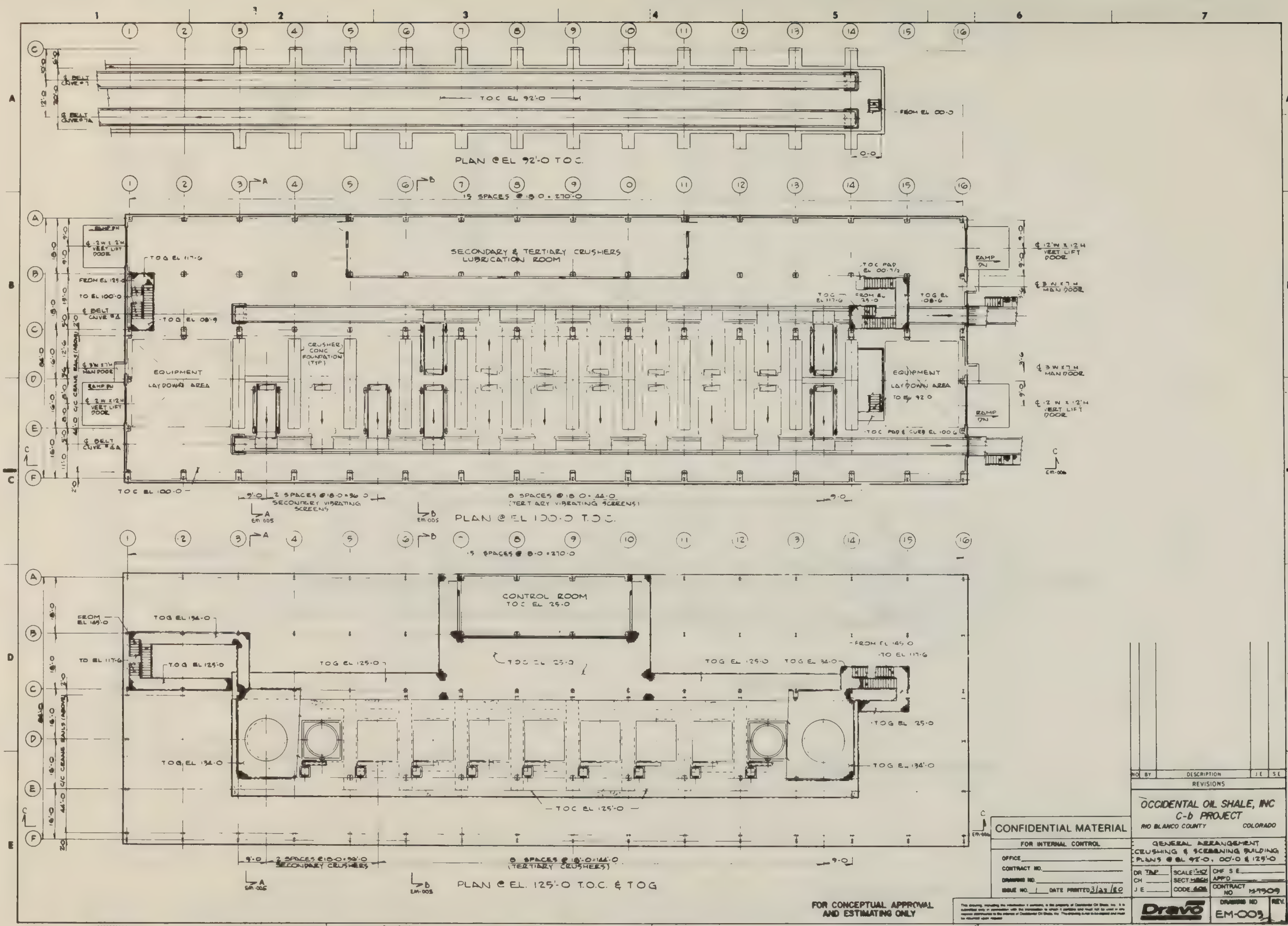
Dravo

DRAWING NO EM-106 REV B

DENVER OPERATIONS OFFICE


ROOF PLAN
PLAN - COVERED STORAGE PILE
TUNNEL PLAN
PLAN @ TOG EL 6942'-0
NOTE ORIENTATION OF THIS PLAN IS SHOWN FOR CNVR #2A (CNVR #2 SIMILAR.
SECTION 'A-A'
SECTION 'B-B'
SECTION 'C-C'
NOTE
FOR CHEM CAL DUST SUPPRESSION SYSTEM SEE FLOW SHEET DWG NO EM-101
33,000 TONS STORAGE CAPACITY
DOMED STORAGE PILE COVER
GRADE EL 6850'-0
ESCAPEWAY ENCLOSURE
VIBRATING BIN DISCHARGER
FUME EXHAUST DUCT
NO BY DESCRIPTION J E S E
REVISIONS
CATHEDRAL BLUFFS SHALE OIL CO.
OCCIDENTAL OIL SHALE, INC., OPERATOR
C-B PROJECT
RIO BLANCO COUNTY COLORADO
GENERAL ARRANGEMENT
RAW SHALE COVERED STORAGE PILE
PLANS & SECTIONS
PRELIMINARY
NOT APPROVED FOR CONSTRUCTION
CONFIDENTIAL MATERIAL
ISSUE NO. 3 DATE PRINTED 1/20/81
CONTRACT NO M-7541
DRAWING NO EM-107
REV
Dravo


CRUSHING AND SCREENING AREA
SPENT HANDLING AND DISPOSAL AREA
PRODUCTION HEADFRAME
RECEIVING HOPPERS
DUST SUPRESSION SYSTEM
1 TON MONORAIL
CNVR TRANSFER TOWER
BELT CNVR No 1
BELT CNVR No 2
BELT CNVR No 2A
BY PASS
EMERGENCY DUMP BIN COARSE ORE
DISCHARGE GATE
120 TON TRUCK
BAGHOUSE
ROTARY VALVE
SCREW CNVR TYP
STACKING TOWER
80,000 TON COARSE ORE STORAGE LIVE+DEAD
VIBRATING BIN BOTTOM
APRON FEEDER TYP
COARSE RECLAIM CNVR
TUNNEL
TO WATER TREATMENT PLANT
TUNNEL - SUMP PUMP
FRONT END LOADER
EMERGENCY STOCK PILE
2 TON MONORAIL
OVERHEAD BRIDGE CRANE - 80 TON
DUST COLLECTION PICK UP LINES (TYP)
FLOP GATE
METAL DETECTOR
BELT SCALE
SCREW CNVR
BELT TRIPPER CNVR No 6
TERTIARY CRUSHER SURGE HOPPERS 1200 TON
BELT FEEDER TYP
TERTIARY CRUSHERS 8 OPER 1 STAND BY
3 SECONDARY CRUSHER 2 OPER - 1 STAND BY
3 SECONDARY PRODUCT SCREENS 2 OPER 1 STAND BY
FINES COLLECTING CNVR
CNVR TRANSFER TOWER
(10) SINGLE DECK TERTIARY PRODUCT VIB SCREENS TPS - 10 OPERATING & STAND BY
BIN FILTER
CONC SILO 30,000 TON FINES STORAGE
(8) BELT FEEDERS
LURGI RETORTING PROCESS PLANT
PRESSURE STEAM MINE RETORT STEAM BLDG
PRODUCT GAS (LPG)
SHALE OIL
PRODUCT NAPTHA
GAS CLEANING PROCESS PLANT
COOLING TOWER
FROM SURFACE FACILITY SUBSTATION
MAKE UP FROM WATER TREATMENT PLANT
SHALE OIL TANK FARM
SOLID WASTE STORAGE BINS 3000 TON
BELT FEEDER TYP
FROM DUST PICK UP
SCRUBBER
MAKE UP WATER
SUMP
PUMPS
STORAGE BIN
SOLID WASTE STOCK PILE
GYPSUM STORAGE BINS - 3
BELT PLOW TYP
WEIGH BELT FEEDERS 2 OPER 1 STAND BY
GAS CLEANING PROCESS PLANT
NOTES
1 SC - SECONDARY CRUSHER
2 TC - TERTIARY CRUSHER
3 SFS - SECONDARY FEED SCREEN
4 SPS - SECONDARY PRODUCT SCREEN
5 TPS - TERTIARY PRODUCT SCREEN
6 (3) TO BE USED INTERMITTENTLY FOR REMOVAL OF FINES STACKING TOWER
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
CONFIDENTIAL MATERIAL
FOR INTERNAL CONTROL
OCCIDENTAL OIL SHALE, INC
C-b PROJECT
RIO BLANCO COUNTY COLORADO
MATERIAL FLOW SHEET
SURFACE FACILITIES
CRUSHING, STORAGE & RETORTING
Dravo
CONTRACT NO M-7509
DRAWING NO EM-001
REV 0


PLAN @ EL 92'-0 T.O.C.
T.O.C. EL 92'-0
FROM EL 00-0
PLAN @ EL 100-0 T.O.C.
15 SPACES @ 18-0 = 270-0
SECONDARY & TERTIARY CRUSHERS LUBRICATION ROOM
EQUIPMENT LAYDOWN AREA
CRUSHER CONC FOUNDATION (TYP)
EQUIPMENT LAYDOWN AREA TO EL 92 0
T.O.C. EL 100-0
2 SPACES @ 18-0 = 36-0 SECONDARY VIBRATING SCREENS
8 SPACES @ 18-0 = 144-0 (TERTIARY VIBRATING SCREENS)
PLAN @ EL. 125'-0 T.O.C. & TOG
CONTROL ROOM T.O.C. EL 25-0
T.O.C. EL 125'-0
2 SPACES @ 18-0 = 36'-0 SECONDARY CRUSHERS
8 SPACES @ 18-0 = 144-0 (TERTIARY CRUSHERS)
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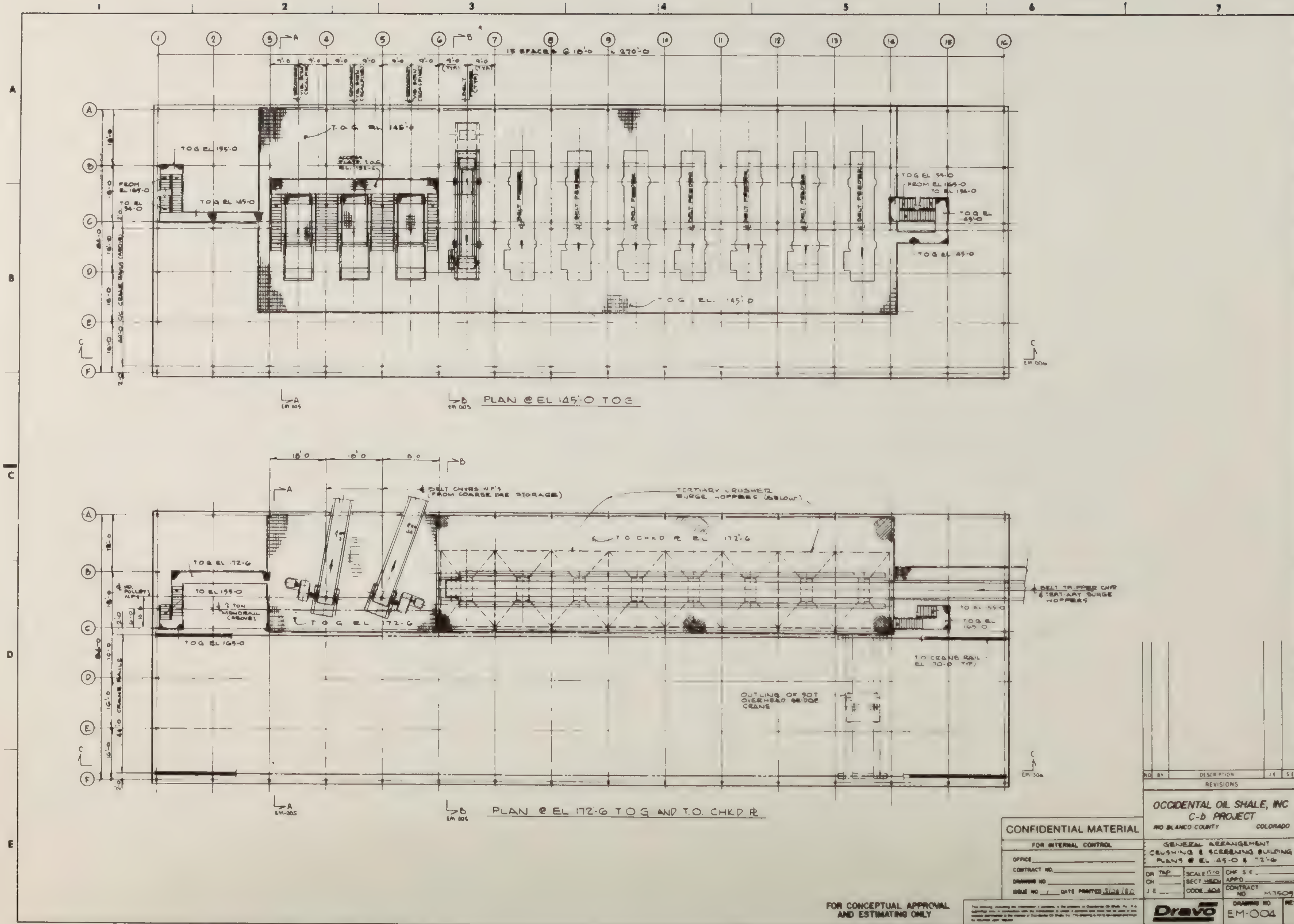
CONFIDENTIAL MATERIAL
FOR INTERNAL CONTROL
OFFICE
CONTRACT NO.
DRAWING NO.
ISSUE NO. 1 DATE PRINTED 3/23/80
NO BY DESCRIPTION JE SE
REVISIONS
OCCIDENTAL OIL SHALE, INC
C-b PROJECT
RIO BLANCO COUNTY COLORADO
GENERAL ARRANGEMENT
CRUSHING & SCREENING BUILDING
PLANS @ EL 92'-0, 100'-0 & 125'-0
DR TAP
CH
J E
CHF S E
APP'D
CONTRACT NO
Dravo
DRAWING NO
EM-003
REV.



PLAN @ EL 145'-0 T.O.G.
PLAN @ EL 172'-6 T.O.G. AND T.O. CHKD PL
15 SPACES @ 18'-0 = 270'-0
T.O.G. EL 145'-0
BELT FEEDER
TERTIARY CRUSHER SURGE HOPPERS (BELOW)
BELT CNVRS NP'S (FROM COARSE ORE STORAGE)
BELT TRIPPER CNVR & TERTIARY SURGE HOPPERS
OUTLINE OF 30T OVERHEAD BRIDGE CRANE
T.O. CRANE RAIL EL 70'-0 (TYP)
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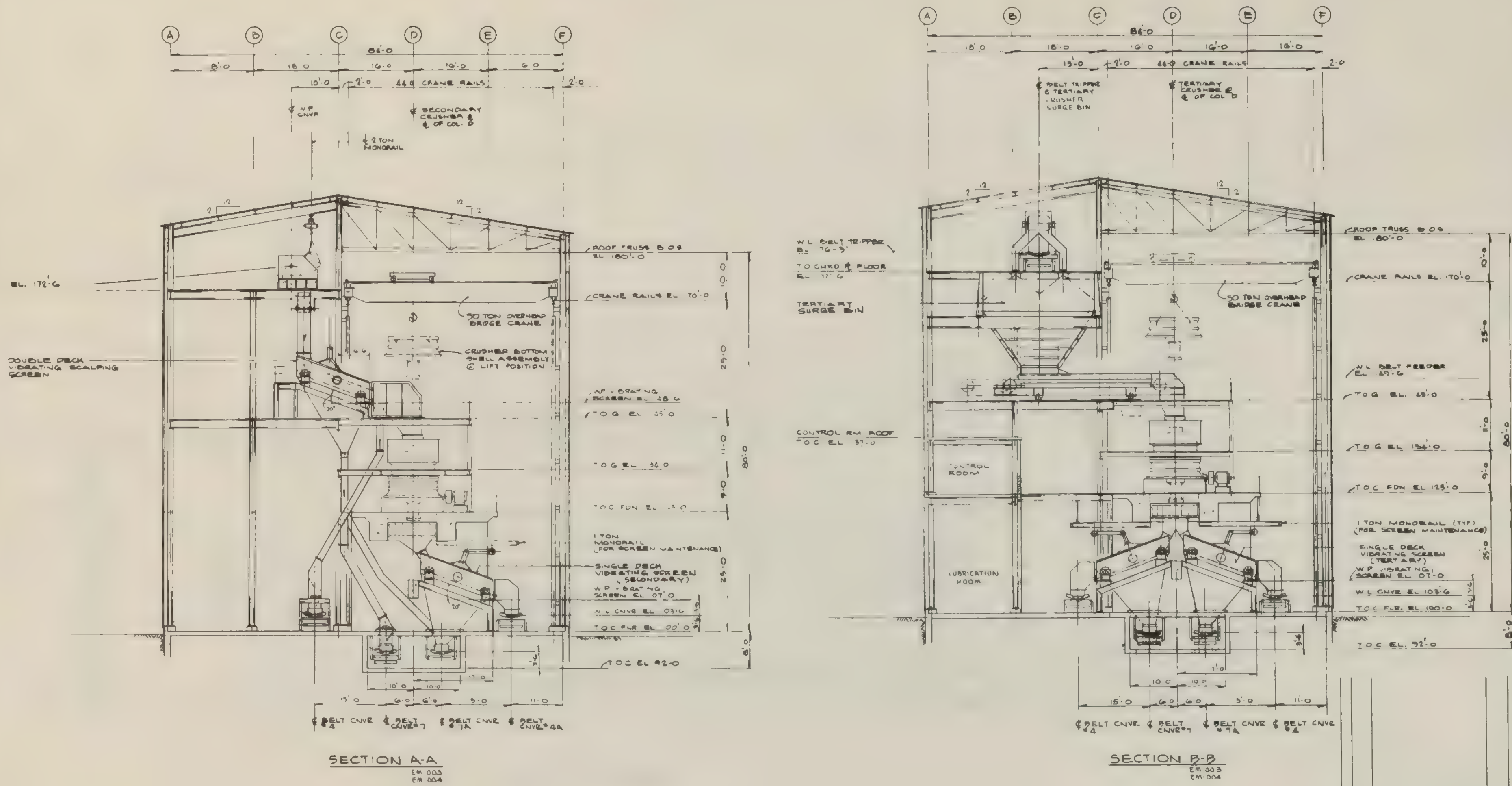
CONFIDENTIAL MATERIAL
FOR INTERNAL CONTROL
REVISIONS
OCCIDENTAL OIL SHALE, INC
C-b PROJECT
RIO BLANCO COUNTY COLORADO
GENERAL ARRANGEMENT CRUSHING & SCREENING BUILDING PLANS @ EL 145'-0 & 172'-6
Dravo
EM-004



NO	BY	DESCRIPTION	E	S.E.
REVISIONS				

OCCIDENTAL OIL SHALE, INC.
C-b PROJECT
RIO BLANCO COUNTY COLORADO

GENERAL ARRANGEMENT
CRUSHING & SCREENING BUILDING
SECTION A-A, B-B

CONFIDENTIAL MATERIAL

FOR INTERNAL CONTROL

OFFICE ______
CONTRACT NO ______
DRAWING NO ______
ISSUE NO 1 DATE PRINTED 3/28/80

DR TBP SCALE 1/8"=1' CHF S.E. ______
CH ______ SECT MECH APPD ______
J.E. ______ CODE 404 CONTRACT NO M7509

Dravo

DRAWING NO EM-005 REV

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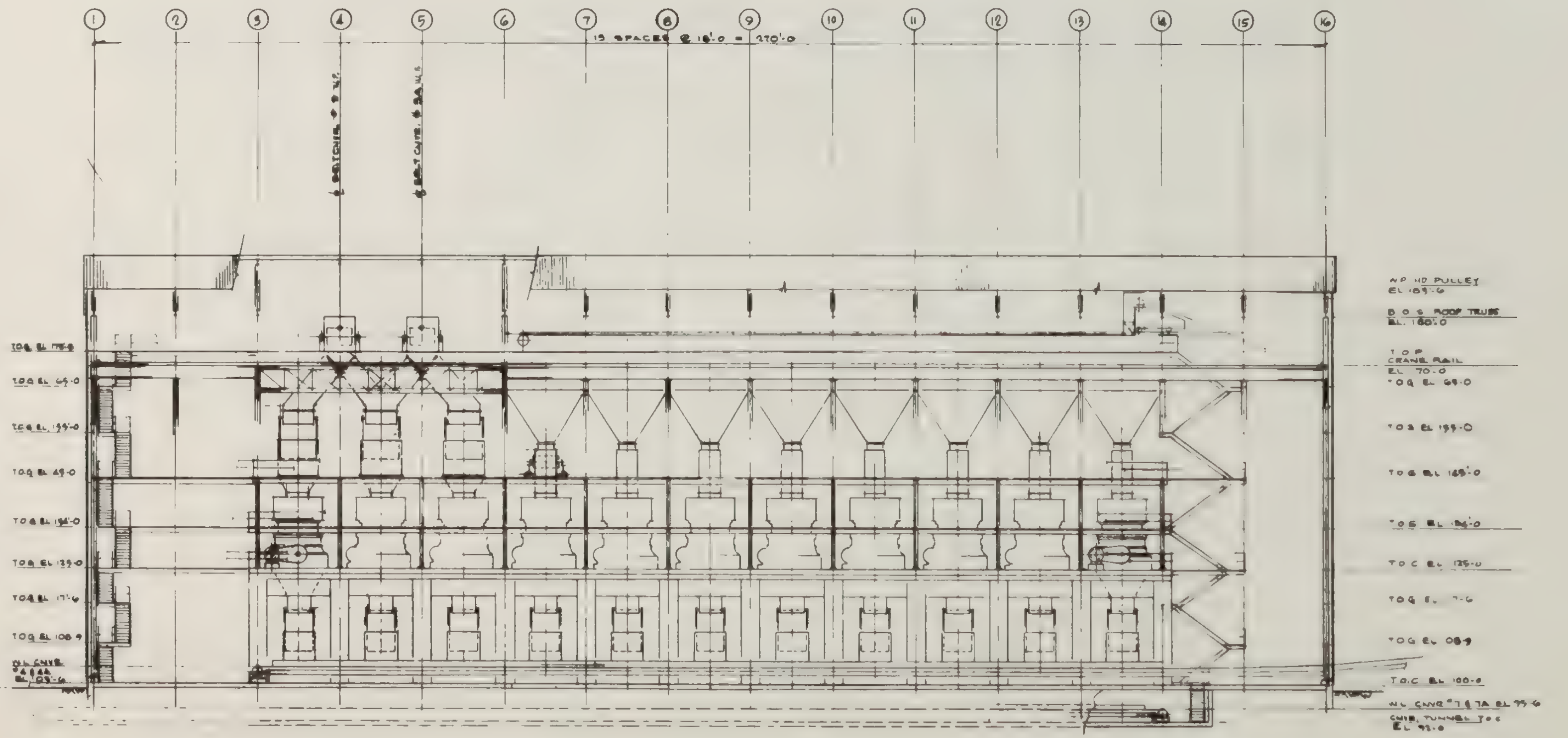

SECTION C-C

EM 003
EM 004

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AND ESTIMATING ONLY

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CONFIDENTIAL MATERIAL

FOR INTERNAL CONTROL

OFFICE ____

CONTRACT NO ____

DRAWING NO ____

ISSUE NO 1 DATE PRINTED 3/28/80

OCCIDENTAL OIL SHALE, INC
C-b PROJECT
RIO BLANCO COUNTY COLORADO

GENERAL ARRANGEMENT
CRUSHING & SCREENING BUILDING
SECTION C-C

DR TAP
CH
JE

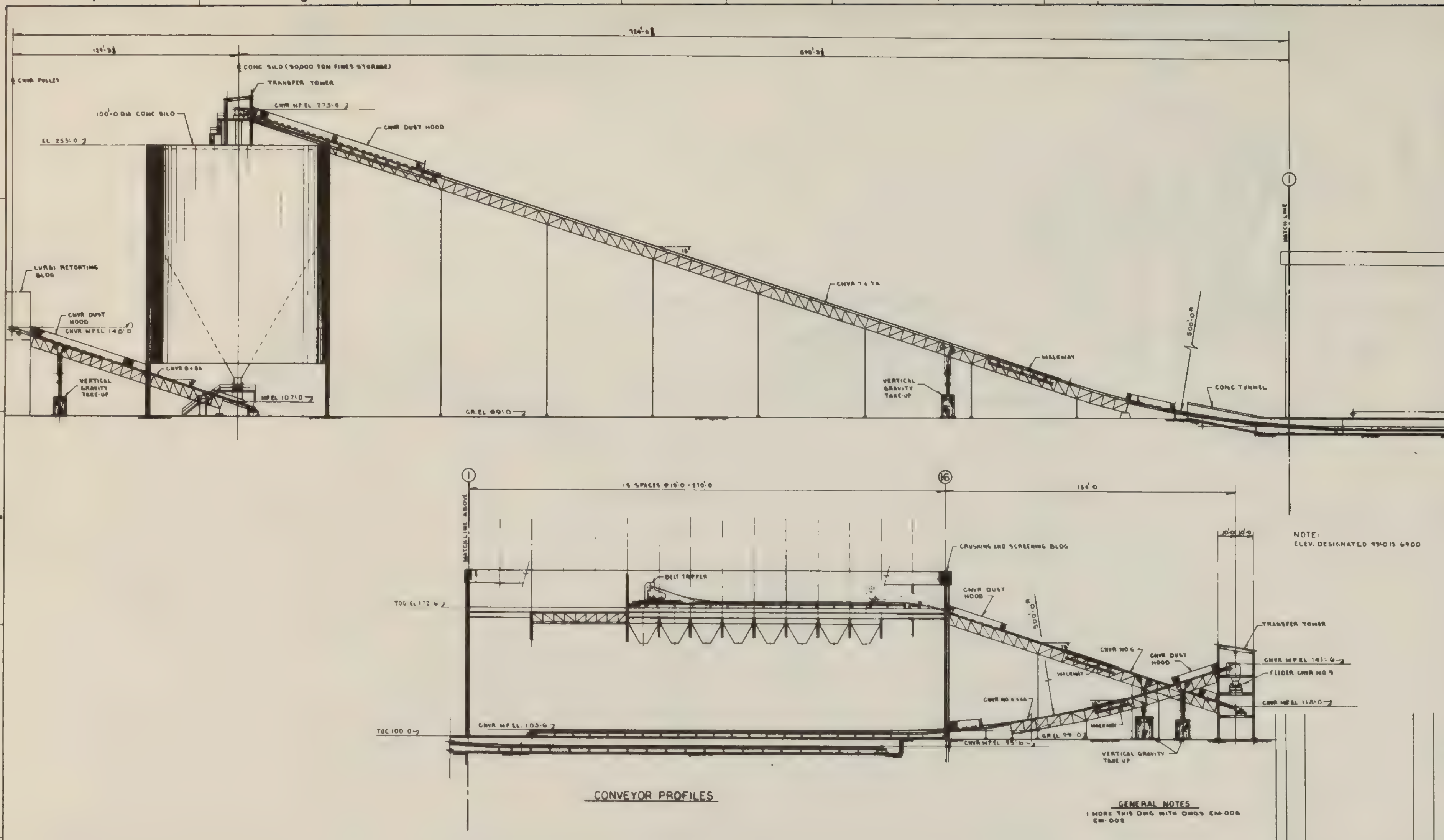
SCALE 1/8
SECT MECH
CODE 404

CHF & E
APPD
CONTRACT NO M7509

Dravo

DRAWING NO EM-006

REV



NO	BY	DESCRIPTION	JE	SE

REVISIONS

OCCIDENTAL OIL SHALE, INC.
C-b PROJECT
RIO BLANCO COUNTY COLORADO

GENERAL ARRANGEMENT
SURFACE FACILITIES
CONVEYOR PROFILES

DR: H FAGAN — SCALE: 1"=40' — CHF S E
CH — SECT: MECH — APP'D
J E — CODE: 404 — CONTRACT NO: M-7509

Dravo — DRAWING NO: EM-007 — REV.

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OFFICE
CONTRACT NO.
DRAWING NO.
ISSUE NO. 1 DATE PRINTED 3/28/80

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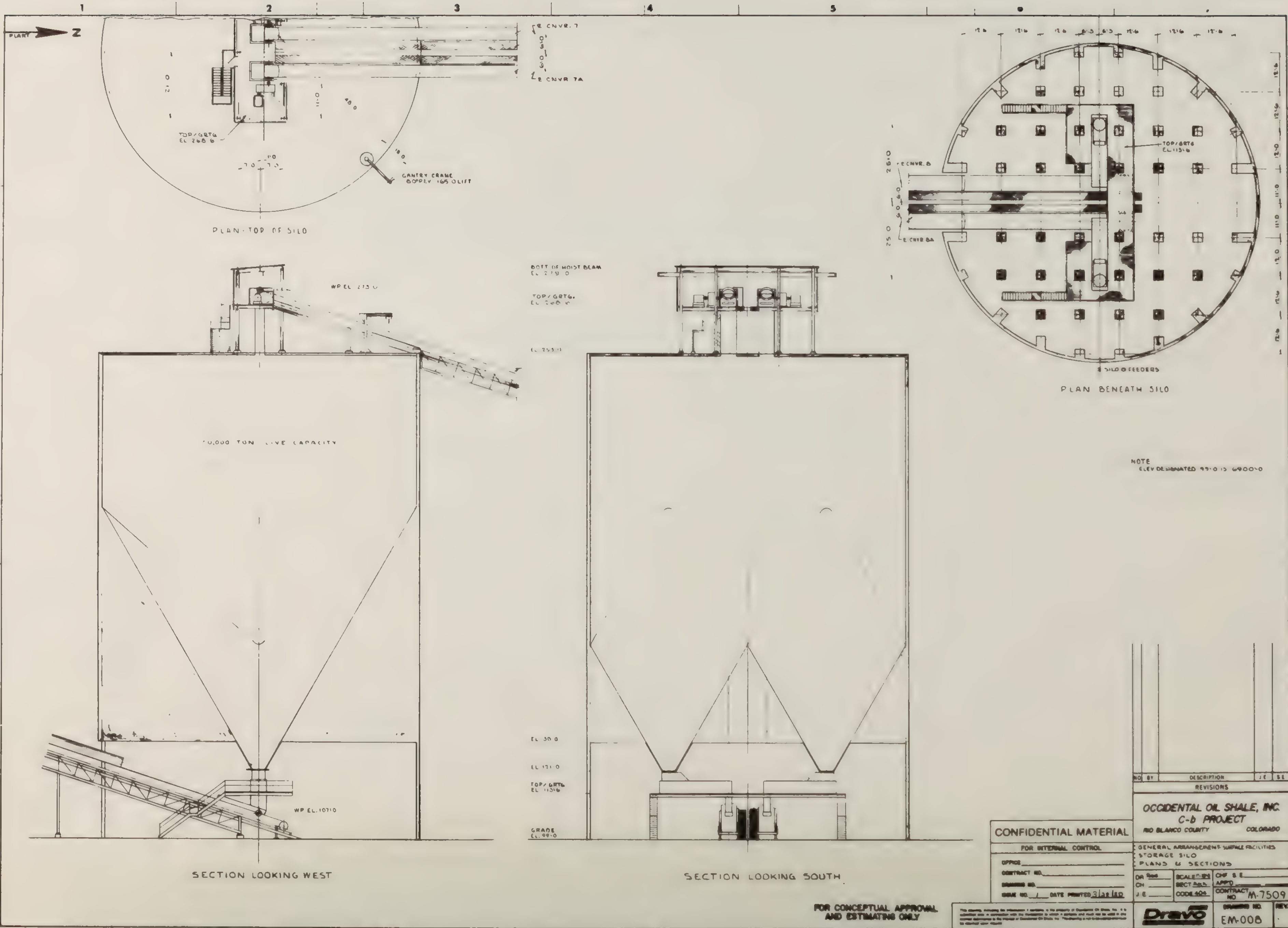


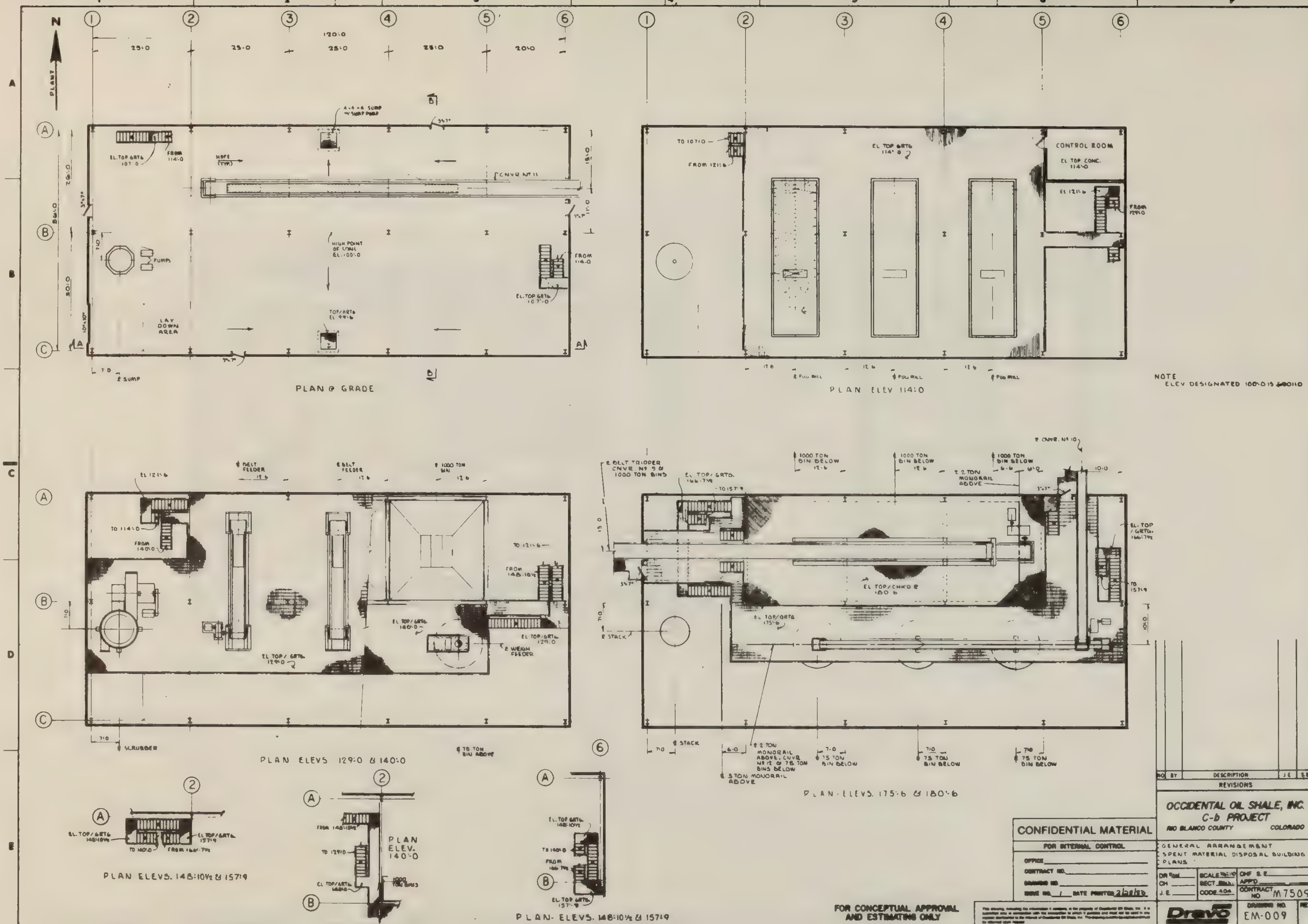
CONFIDENTIAL MATERIAL
FOR INTERNAL CONTROL

OCCIDENTAL OIL SHALE, INC.
C-b PROJECT
RIO BLANCO COUNTY COLORADO

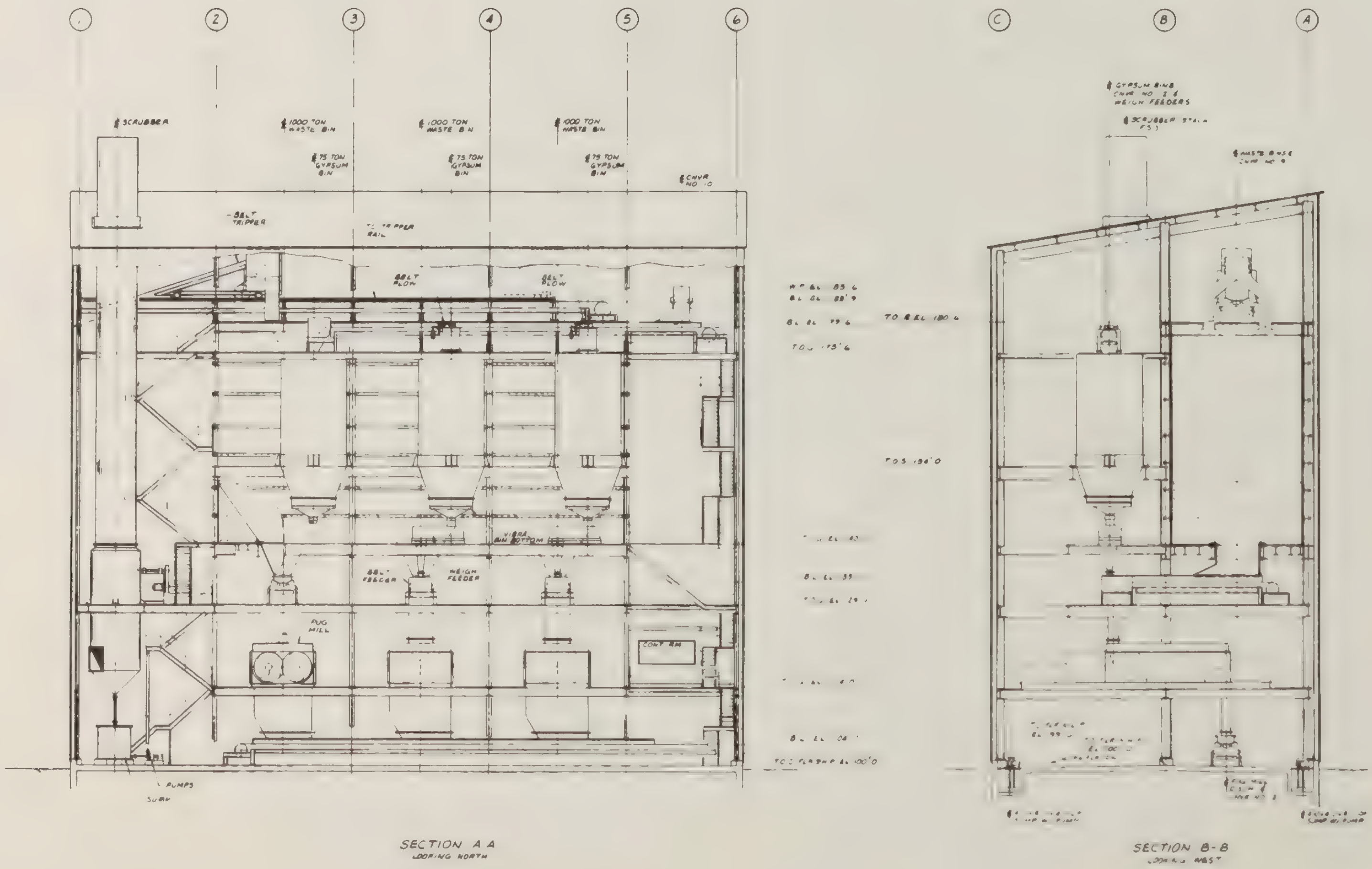
GENERAL ARRANGEMENT SURFACE FACILITIES
STORAGE SILO
PLANS & SECTIONS

CONTRACT NO. M-7509
DRAWING NO. EM-008

FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY



PLAN @ GRADE
PLAN ELEV 114:0
NOTE
ELEV DESIGNATED 100'-0 IS 6800.0
CONTROL ROOM
PLAN ELEVS 129:0 & 140:0
PLAN ELEVS. 175'-6 & 180'-6
PLAN ELEVS. 148:10½ & 157:9
PLAN ELEV. 140'-0
PLAN - ELEVS. 148:10½ & 157:9
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
CONFIDENTIAL MATERIAL
FOR INTERNAL CONTROL
REVISIONS
OCCIDENTAL OIL SHALE, INC.
C-b PROJECT
RIO BLANCO COUNTY
COLORADO
GENERAL ARRANGEMENT
SPENT MATERIAL DISPOSAL BUILDING
PLANS
Dravo
M7509
EM-009



SECTION A A
LOOKING NORTH

SECTION B-B
LOOKING WEST

FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY

NO	BY	DESCRIPTION	J E	S E

REVISIONS

CONFIDENTIAL MATERIAL
FOR INTERNAL CONTROL
OFFICE
CONTRACT NO.
DRAWING NO
ISSUE NO ____ DATE PRINTED 3/28/80

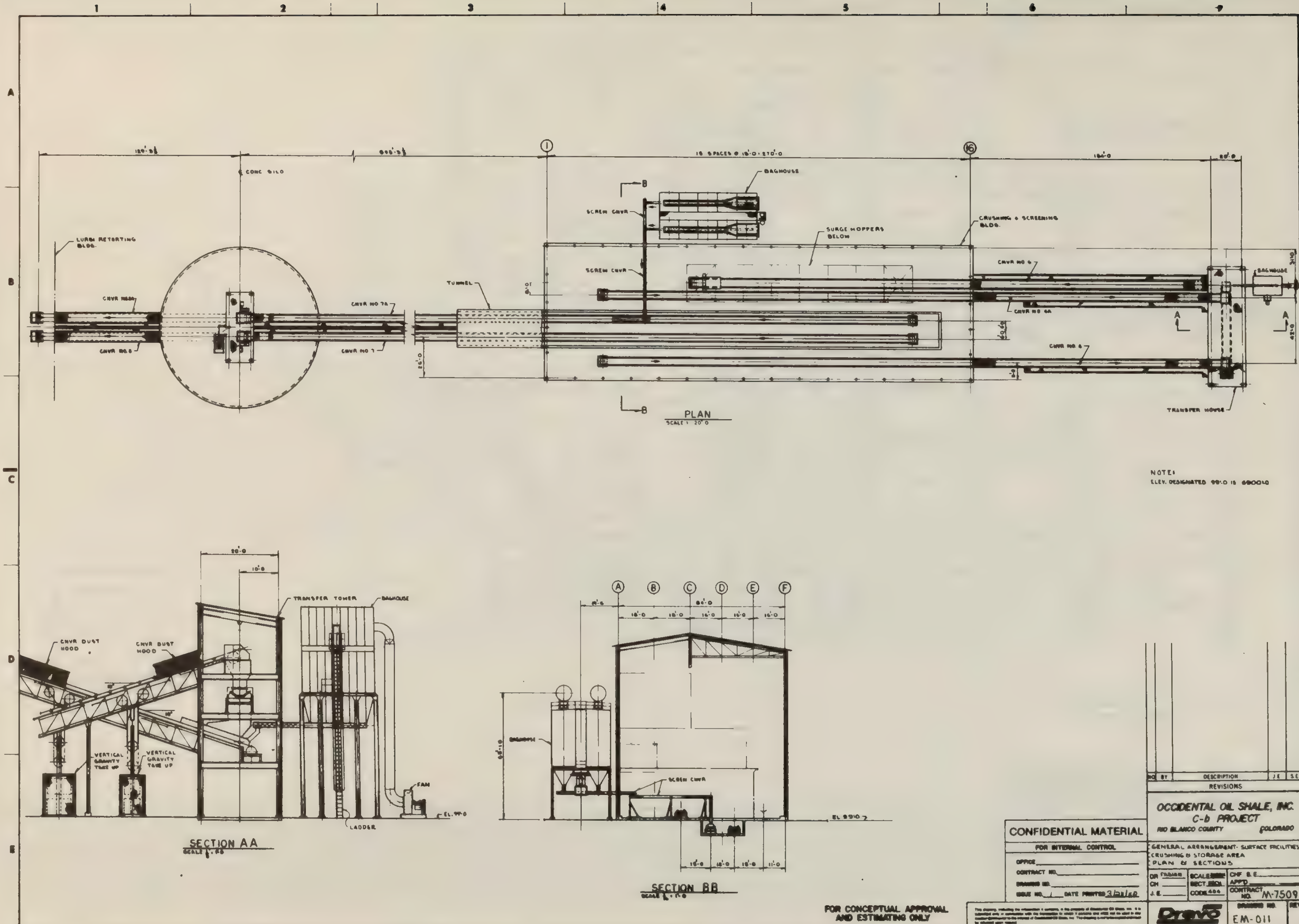
OCCIDENTAL OIL SHALE, INC.
C-b PROJECT
RIO BLANCO COUNTY COLORADO

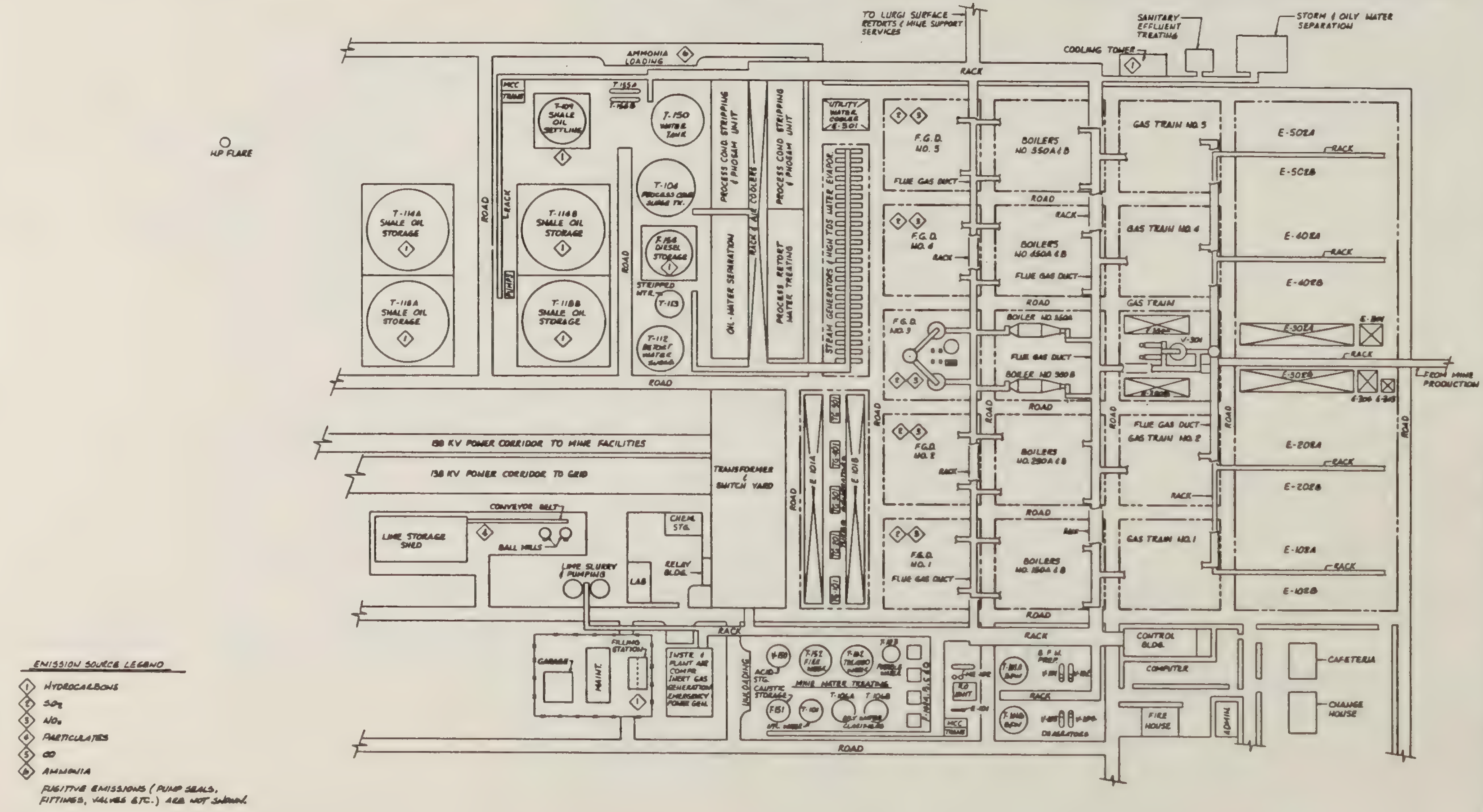
GENERAL ARRANGEMENT
SPENT MATERIAL DISPOSAL BUILDING
SECTIONS

DR TC
CH
J E
SCALE 1'-0
SECT 424
CODE 4864
CHF S E
APP'D
CONTRACT NO M-7509

Dravo

DRAWING NO EM-010
REV


PLAN
SCALE 1" = 20'-0"
LURGI RETORTING BLDG.
CONC SILO
CNVR NO. 7A
CNVR NO. 7
CNVR NO. 8
TUNNEL
SCREW CNVR
BAGHOUSE
SURGE HOPPERS BELOW
CRUSHING & SCREENING BLDG.
CNVR NO. 6
CNVR NO. 6A
TRANSFER HOUSE
15 SPACES @ 18'-0 = 270'-0
NOTE:
ELEV. DESIGNATED 99'-0 IS 6900'-0
SECTION AA
CNVR DUST HOOD
VERTICAL GRAVITY TAKE UP
TRANSFER TOWER
LADDER
FAN
SECTION BB
SCREW CNVR
EL 99'-0
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
CONFIDENTIAL MATERIAL
FOR INTERNAL CONTROL
REVISIONS
OCCIDENTAL OIL SHALE, INC.
C-b PROJECT
RIO BLANCO COUNTY COLORADO
GENERAL ARRANGEMENT - SURFACE FACILITIES
CRUSHING & STORAGE AREA
PLAN & SECTIONS
CONTRACT NO. M-7509
Dravo
EM-011

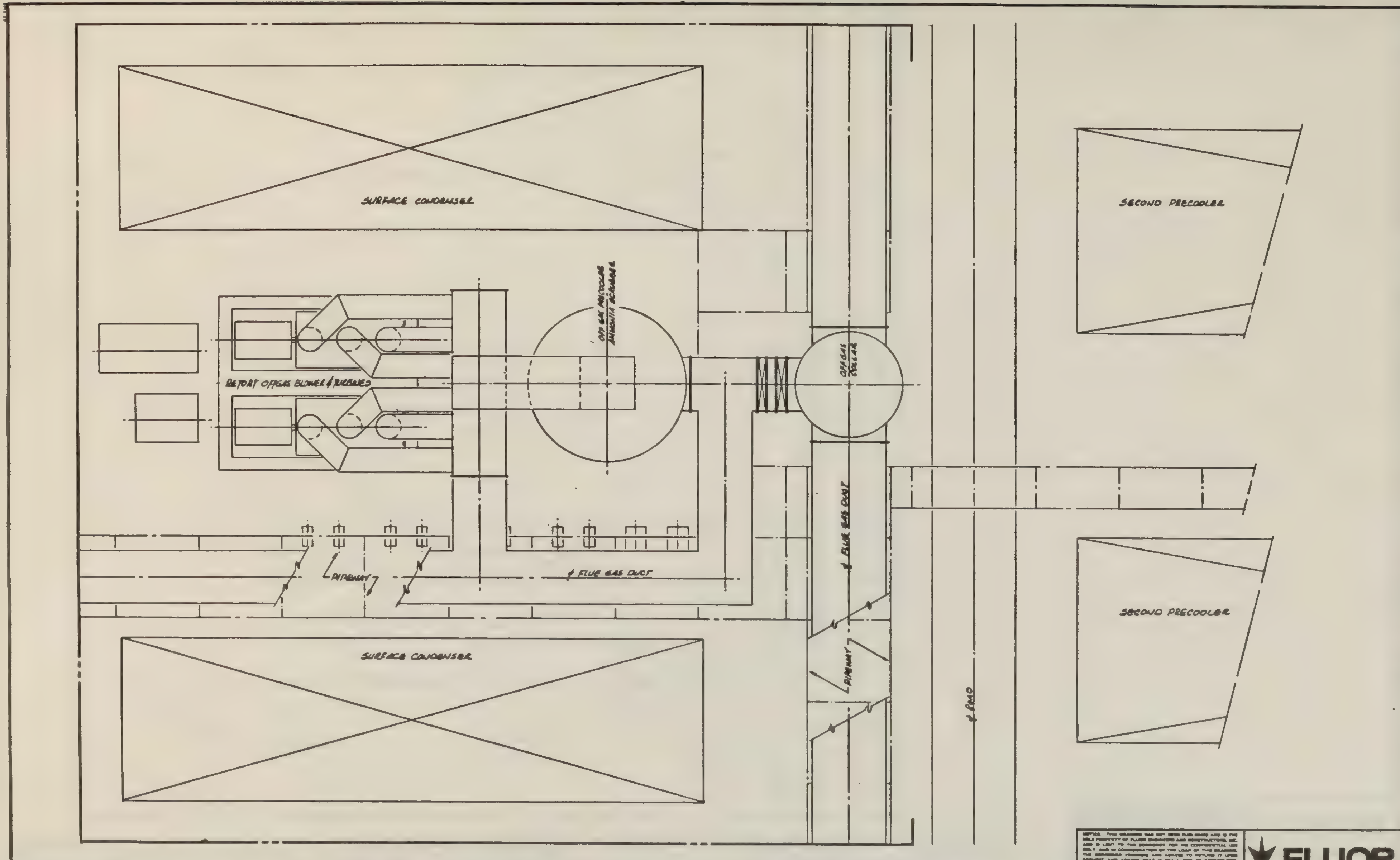


FLUOR

OVERALL PLOT PLAN
CASE V · 600 PSIG MODULAR STEAM PLANT
COMMERCIAL SURFACE PROCESS FACILITIES
OCCIDENTAL OIL SHALE — TRACT C-b COLORADO

TURCOTTE
ESERSOLE
B. TAYLOR

Scale: 1"=100'
650239-4-00-001-VB
0



NUMBER	REFERENCE DRAWINGS
4.00.001.78	OVERALL PLOT PLAN
4.053	PLOT ELEVATION - SCRUBBER AREA

FLUOR

PLOT PLAN
SCRUBBER AREA

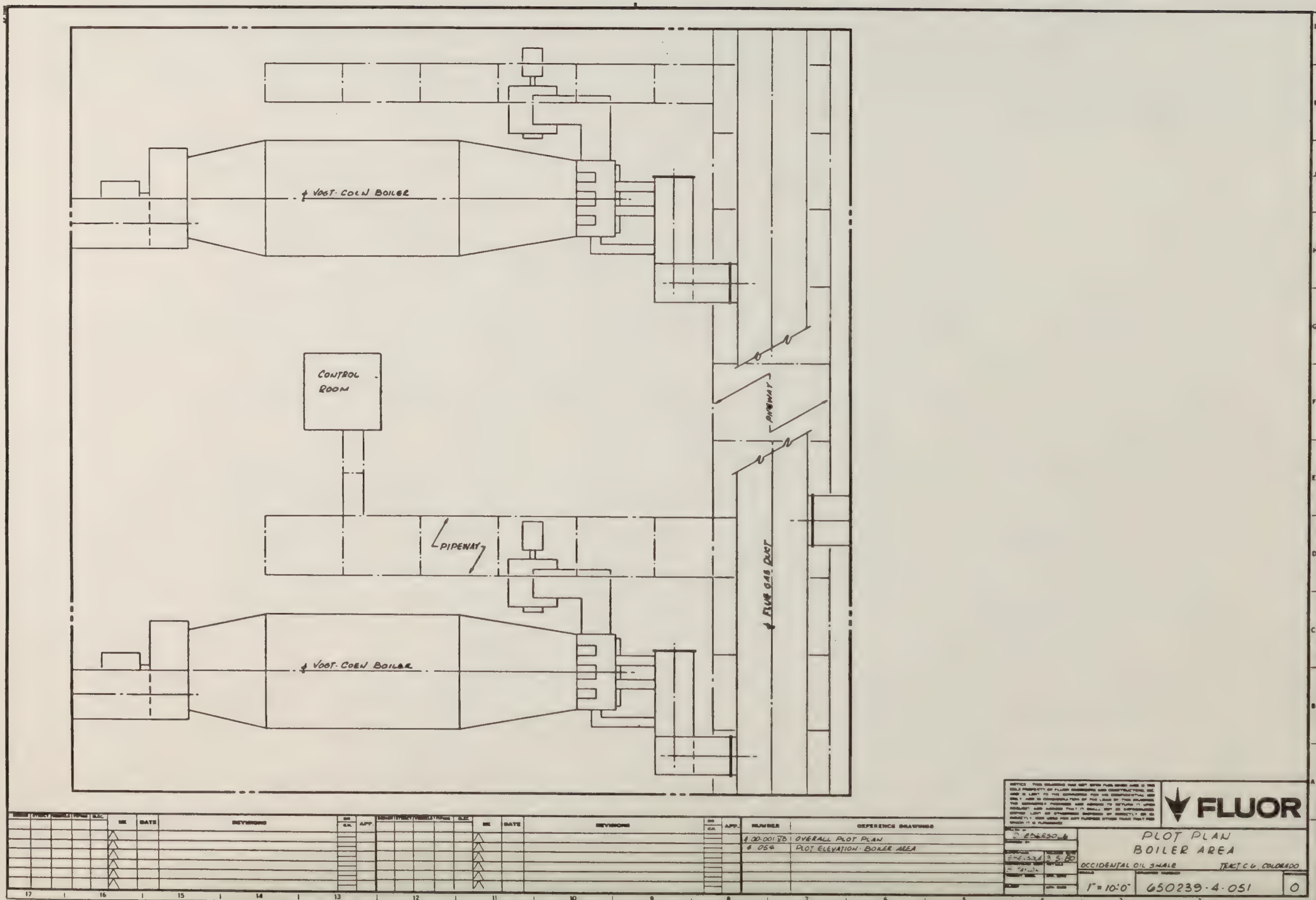
OCCIDENTAL OIL SHALE — TRACT C-b, COLORADO

C. EBERSOLE

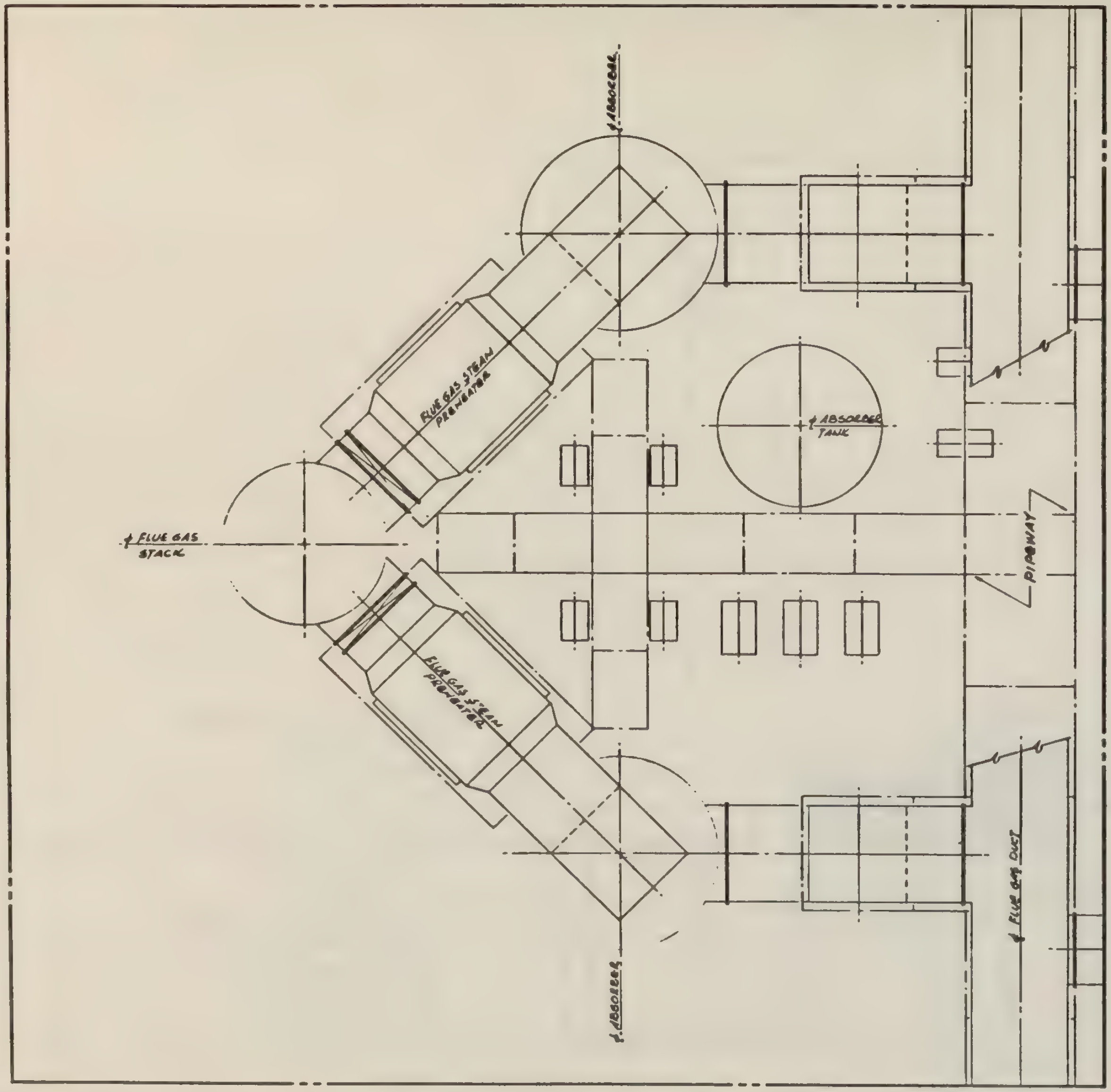
1" = 10'-0"

650239-4-050

0



℄ VOGT-COEN BOILER
CONTROL ROOM
PIPEWAY
PIPEWAY
℄ FLUE GAS DUCT
℄ VOGT-COEN BOILER
REVISIONS
REFERENCE DRAWINGS
4-00-001-78 OVERALL PLOT PLAN
4-054 PLOT ELEVATION-BOILER AREA
FLUOR
PLOT PLAN
BOILER AREA
OCCIDENTAL OIL SHALE
TRACT C-b, COLORADO
1" = 10'-0"
650239-4-051
0



NUMBER	REFERENCE DRAWINGS
J-00-001 TB	OVERALL PLOT PLAN
J-055	PLOT ELEVATION - ABSORBER AREA

FLUOR

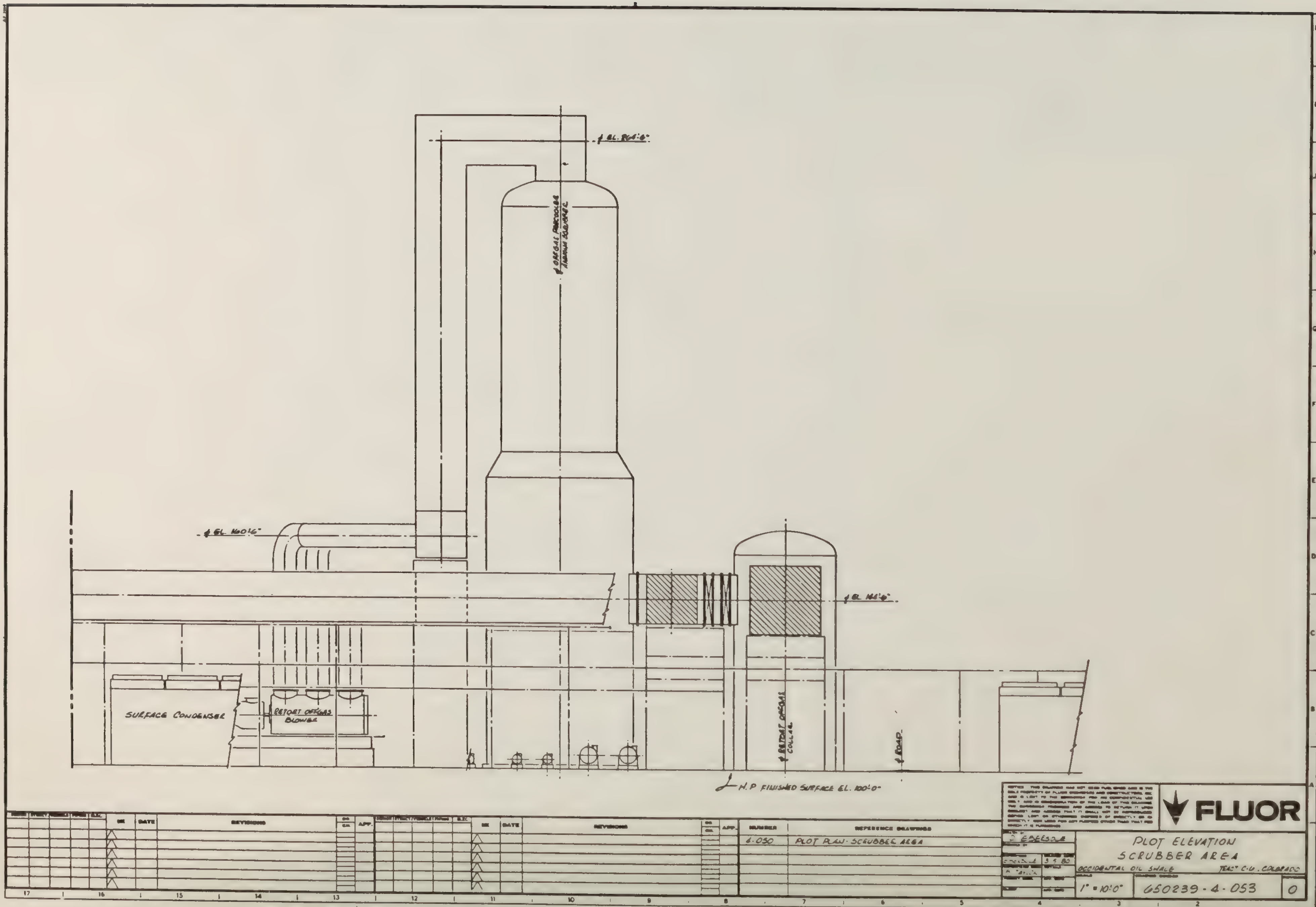
PLOT PLAN
FGD AREA

OCCIDENTAL OIL SHALE — TRACT C-b, COLORADO

D. EBERSOLE

Scale: 1" = 10'-0"

650239-4-052 — 0



℄ EL. 204'-6"
℄ OFFGAS PRECOOLER ABSORBER
℄ EL. 160'-6"
℄ EL. 146'-6"
SURFACE CONDENSER
RETORT OFFGAS BLOWER
℄ RETORT OFFGAS COLLAR
℄ ROAD
H.P. FINISHED SURFACE EL. 100'-0"
REVISIONS
REFERENCE DRAWINGS
6-050 PLOT PLAN - SCRUBBER AREA
FLUOR
PLOT ELEVATION
SCRUBBER AREA
OCCIDENTAL OIL SHALE
TRACT C-b, COLORADO
1" = 10'-0"
650239-4-053
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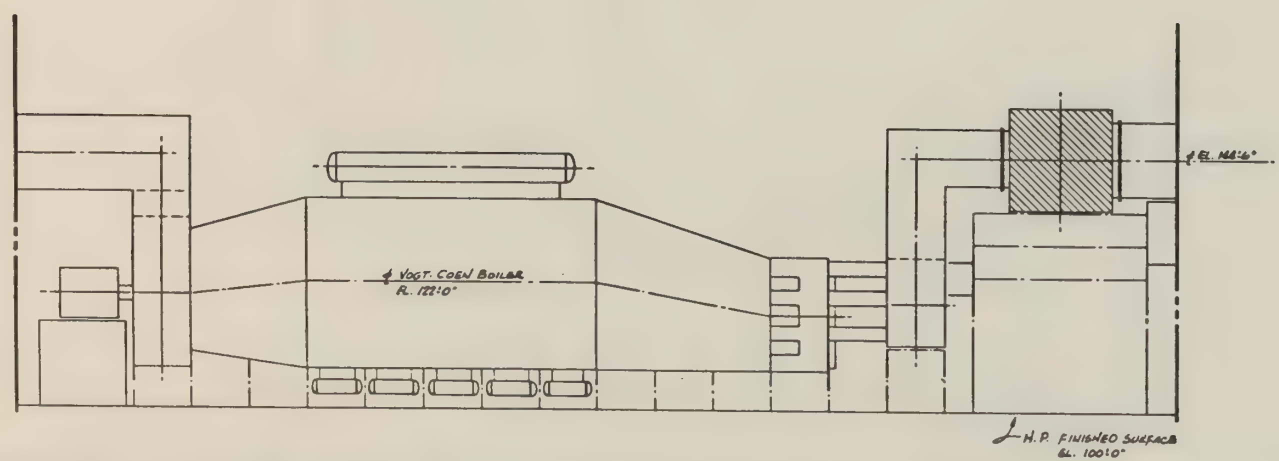


NUMBER	REFERENCE DRAWINGS
4-051	PLOT PLAN - BOILER AREA

FLUOR

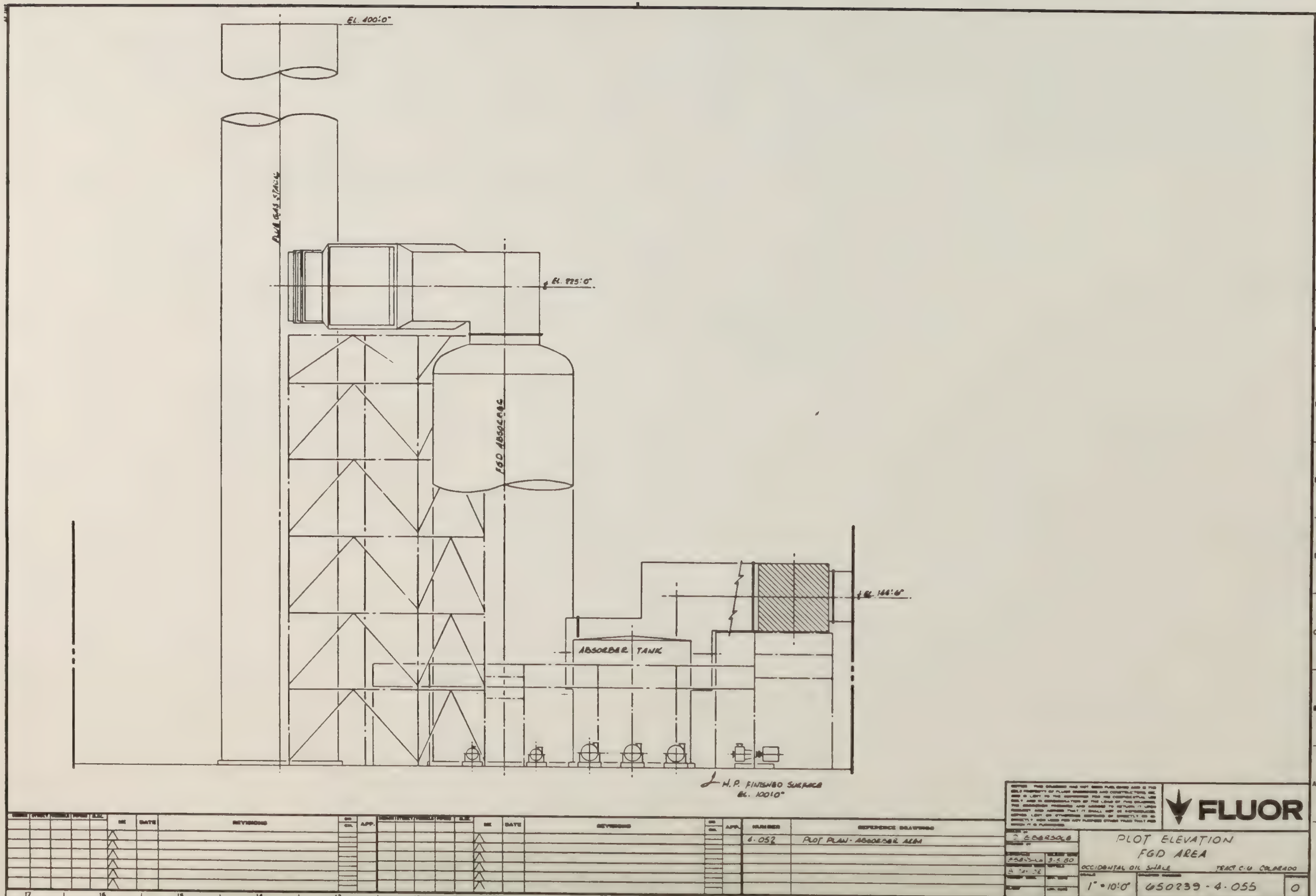
PLOT ELEVATION
BOILER AREA

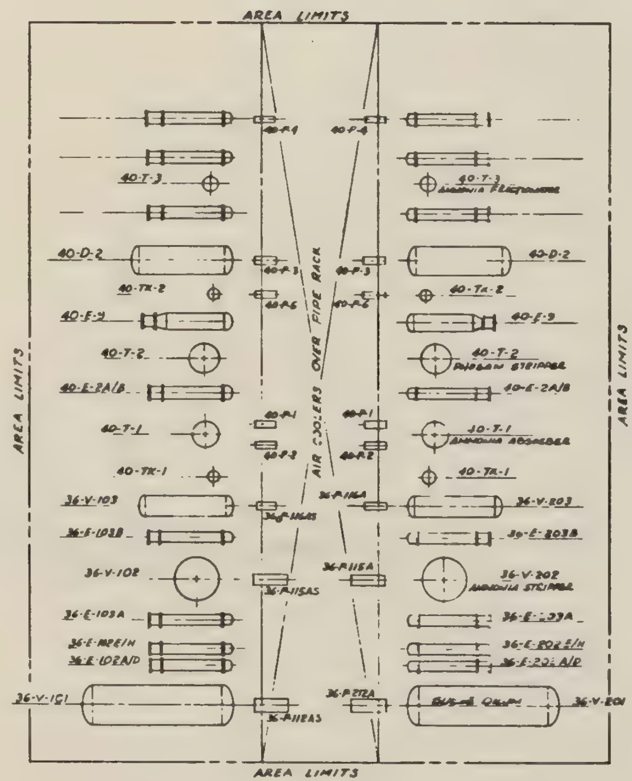
OCCIDENTAL OIL SHALE — TRACT C-b COLORADO

D. EBERSOLE

SCALE: 1" = 10'-0"

650239-4-054 — 0


EL. 400'-0"
FGD ABSORBER
ABSORBER TANK
EL. 144'-6"
H.P. FINISHED SURFACE
EL. 100'-0"
REVISIONS
REFERENCE DRAWINGS
4-052
PLOT PLAN - ABSORBER AREA
FLUOR
PLOT ELEVATION
FGD AREA
OCCIDENTAL OIL SHALE
TRACT C-b COLORADO
1" = 10'-0"
650239-4-055
0



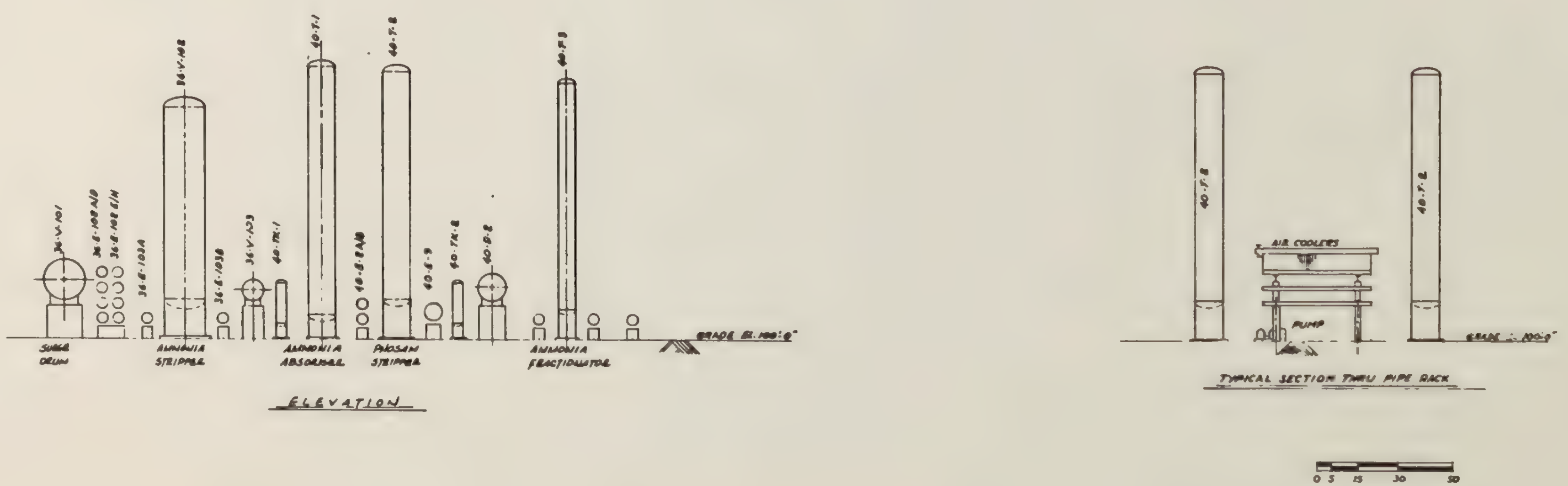
NUMBER	REFERENCE DRAWINGS
4-??? 80	OVERALL PLOT PLAN
4-057	PLOT ELEVATION

W I ENLOW
EBERSOLE 3 5 80
B TAYLOR

FLUOR

PLOT PLAN
PROCESS CONDENSATE TREATING AND FACILITY
COMMERCIAL SURFACE PROCESS FACILITIES
OCCIDENTAL OIL SHALE TRACT C-b COLORADO

Scale: 1"=20'-0"
Drawing number: 650239-4-056
Revision: 0



NUMBER	REFERENCE DRAWINGS
4-056	PLOT PLAN

FLUOR

SECTION AND ELEVATION
PROCESS CONDENSATE TREATING AND PHOSAM
COMMERCIAL SURFACE PROCESS FACILITIES
OCCIDENTAL OIL SHALE TRACT C-b, COLORADO

W. ENLOW
3-5-80
S. TAYLOR

SCALE 1"=20'-0"

650239-4-057

0

5.0

APPENDIX 5.0

SO_2 Control Process Descriptions

Appendix 5.0

Table of Contents

SO_2 Control Process Descriptions

WELLMAN-LORD PROCESS

Process Description

The Wellman-Lord Process is a proven regenerative-type desulfurization process for treatment of boiler flue gas (Figures A5-1 and A5-2). Sulfur dioxide removal efficiencies of greater than 90% have been demonstrated. In the Wellman-Lord Process, sulfur dioxide is removed from the flue gas with a sodium sulfite scrubbing solution. The concentrated aqueous SO_2 stream which is produced can be processed into elemental sulfur or sulfuric acid. The process can be divided into four basic steps: flue gas pretreatment, absorption, regeneration, and purge treatment. A fifth step, the processing of SO_2 into sulfur by-products, is not necessarily an integral part of the Wellman-Lord Process but is generally associated with Wellman-Lord installations.

In the pretreatment step, boiler flue gas is pretreated by contact with water in a venturi scrubber. This step cools and saturates the gas, absorbs corrosive chlorides, and removes some of the particles remaining in the gas after any upstream particle removal efforts. Particulate removal is necessary to minimize the pressure drop buildup in the absorber and to keep particulates from concentrating in the regeneration evaporator. The particulates which are removed exit in a slurry which may be pumped to an ash disposal pond or other disposal site.

The cool saturated gas then flows to an absorber where it is contacted with a sodium sulfite solution. Desulfurized flue gas leaves the absorber and is discharged through a stack to the atmosphere. The principal reaction in the absorber is between sulfur dioxide in the flue gas and sodium sulfite in the absorbing solution:

$$SO_2 + Na_2SO_3 + H_2O \dashrightarrow 2NaHSO_3$$

When water is removed from a sodium bisulfite solution, sodium pyrosulfite, $Na_2S_2O_5$, is formed:

$$2NaHSO_3 \dashrightarrow Na_2S_2O_5 + H_2O$$

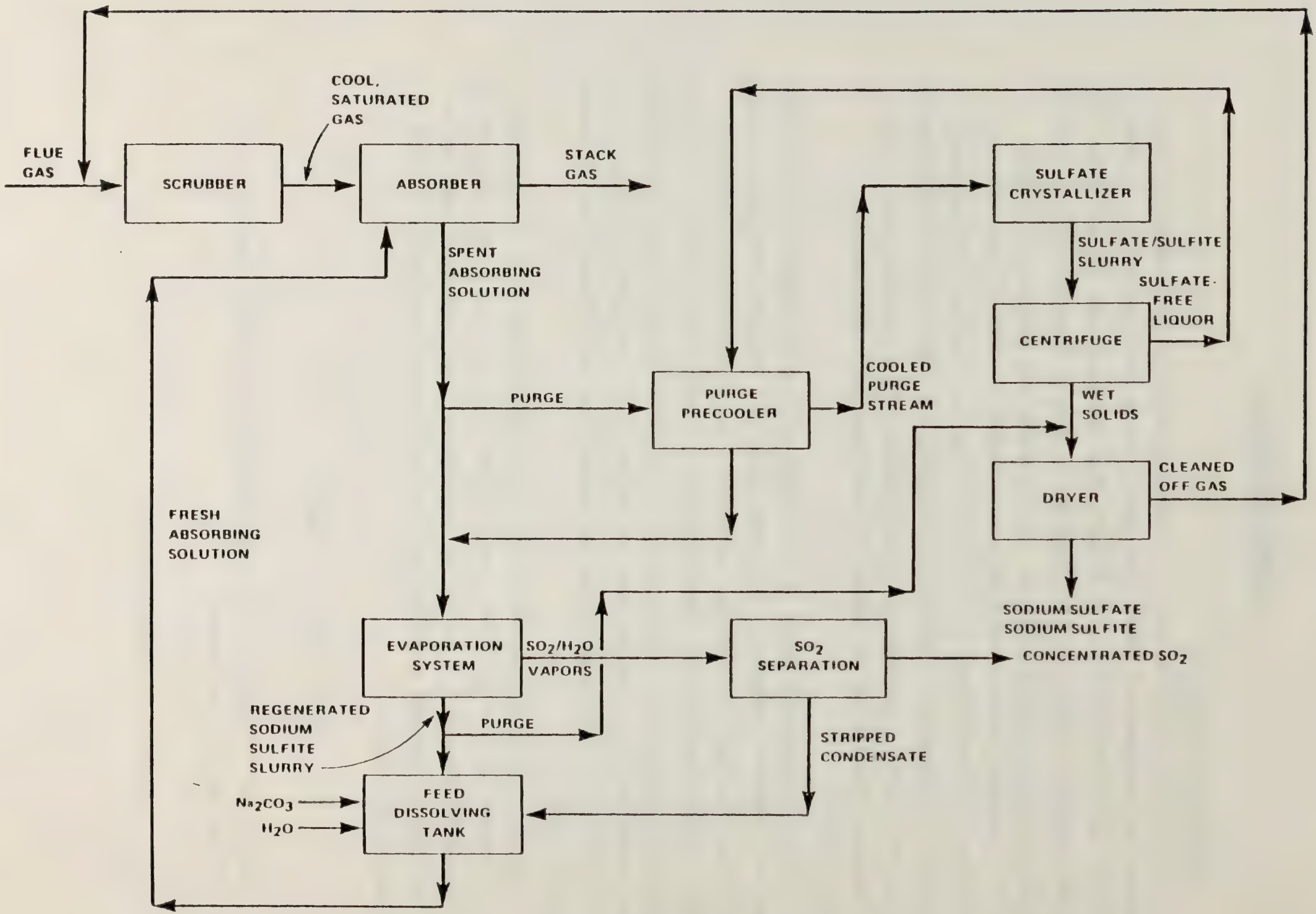


FIGURE A5-1. WELLMAN-LORD PROCESS

FIGURE A5-2

WELLMAN-LORD PROCESS

ABSORPTION:

$SO_2 + Na_2SO_3 + H_2O) ---> 2NaHSO_3$
(SODIUM SULFITE) (SODIUM BISULFITE)

$SO_2 + Na_2CO_3 ---> Na_2SO_3 + CO_2$
(SODIUM CARBONATE)
(OR SODA ASH)

$SO_3^{-2} + 1/2O_2 ---> SO_4^{-2}$
(SULFITE) (SULFATE)

REGENERATION:

$6NaHSO_3 ---> 2Na_2SO_4 + Na_2S_2O_3 + 2SO_2 + 3H_2O$
(SODIUM SULFATE) (SODIUM PYROSULFITE)

$2NaHSO_3 + 2Na_2SO_3 ---> 2Na_2SO_4 + Na_2S_2O_3 + H_2O$

$2NaHSO_3 + SO_2 + H_2O + Na_2SO_3$

Makeup soda ash (Na_2CO_3) also reacts with SO_2 in the absorber to form additional sodium sulfite according to the following reaction:

$$Na_2CO_3 + SO_2 \longrightarrow Na_2SO_3 + CO_2$$

Part of the sodium sulfite is oxidized to sodium sulfate. If sulfur trioxide or oxygen is present in the flue gas, the following reactions may also occur:

$$2Na_2SO_3 + SO_3 \longrightarrow Na_2SO_4 + Na_2S_2O_5$$

$$2Na_2SO_3 + O_2 \longrightarrow 2Na_2SO_4$$

The sodium sulfate is unreactive and of no further use to the Wellman-Lord Process.

The effluent from the absorber, rich in sodium bisulfite and also containing some sodium sulfite and sodium sulfate, is split into two streams. Approximately 15 percent of the effluent is sent to the purge treatment area for sulfate removal. The remaining 85 percent goes to the regeneration area.

Regeneration of the spent absorption solution is accomplished in a forced circulation evaporator. The absorber effluent is heated to convert sodium bisulfite to sodium sulfite while releasing sulfur dioxide and water vapors:

$$2NaHSO_3 \longrightarrow Na_2SO_3 + SO_2 + H_2O$$

The regeneration reaction is limited by the equilibrium concentration of sulfite ion in solution. Since sodium sulfite is less soluble than sodium bisulfite, it is continuously removed from solution by crystallization, thus driving the regeneration reaction forward. The regenerated sodium sulfite slurry is fed directly to a feed dissolving tank. The high temperature in the evaporator also causes the formation of small amounts of sodium sulfate and sodium thiosulfate ($Na_2S_2O_3$) according to:

$$6NaHSO_3 \longrightarrow 2Na_2SO_4 + Na_2S_2O_3 + 2SO_2 + 3H_2O$$

$$2NaHSO_3 + 2Na_2SO_3 \longrightarrow 2Na_2SO_4 + Na_2S_2O_3 + H_2O$$

The overhead vapor stream from the evaporator is passed through a consenser/separator to remove most of the water vapor and to concentrate the SO_2. The condensate is steam stripped to remove dissolved SO_2 and then sent to the feed dissolving tank. The overhead stream from the condenser, which now contains about 15 volume percent water and 85 volume percent SO_2, is sent to an SO_2 processing area. This concentrated SO_2 stream may be dried and marked without further processing, reduced to elemental sulfur, or oxidized and reacted with water to form sulfuric acid.

In the feed dissolving tank, a makeup solution of sodium carbonate in water is added to the stripped condensate and regenerated sulfite liquor from the evaporator. The makeup water compensates for water lost from the system and for sodium purged as nonregenerable salts.

The contents of the tank are agitated and the resulting solution is recycled to the absorber.

About 15 percent of the bisulfite-rich stream leaving the absorber is sent to the purge treatment area for removal of sodium sulfate. The purge stream is precooled by heat exchange with cold sulfate-free liquor returning from purge treatment. The stream then enters a chiller-crystallizer where it is further cooled to 32°F, causing a mixture of sodium sulfate and sodium sulfite to crystallize. The sodium sulfate/sodium sulfite slurry is then centrifuged to produce a 90 percent solids cake. The clarified liquor, essentially sulfate free, is used to precool the incoming purge stream and is returned to the absorber liquid stream entering the regeneration step.

In addition to the primary purge stream, a small amount of liquor is removed from the evaporators to help prevent a buildup of impurities that result from regeneration. This secondary purge stream is added to the solids cake from the centrifuge before drying. The crystalline by-product from the drying step is a mixture of anhydrous sodium sulfate (70 percent) and sodium sulfite, with small quantities of thiosulfates, pyrosulfites, and chlorides.

Offgas from the dryer is cleaned, generally in a cyclone and/or baghouse, and recovered dust is added to the dryer product. The cleaned offgas is routed to the main flue gas stream upstream of the prescrubber and processed with the flue gas for SO_2 recovery.

Advantages:

1) Scrubbing solution is regenerable.

Disadvantages

1) Cost of the Wellman-Lord plant is much higher than other competing FGD processes.

2) "Black-box" blowdown solution regeneration system is not yet proven.

3) No provisions for disposal of scrubber blowdown are made.

Commercial Installations

More than two dozen Wellman-Lord Process units were on-stream as of late 1977 in the U.S. Most of these are located in Japan, with U.S. facilities owned by Chevron, Olin, Allied, and Northern Indiana Public Service Company. Start-ups have recently been completed on three units for the Public Service Company of New Mexico, two of which are 350 MW coal-fired boilers and one 550 MW coalfired boiler.

Licensor

DM International, Inc.

PROCESS ECONOMIC SURVEY

System Size	500 MW
Fuel	Coal (3.5% S)
SO_2 Removal	90%
Total Capital Investment	
(Capital investment plus working capital)	42.4 MM \$
Total Operating Costs	
(Direct plus indirect)	18.2 MM \$
Utility Requirements	
Natural gas	1.40 MM SCFD
Steam	244 M lb/hr
Heat Credit	7.18 MM Btu/hr
Process water	18,900 GPM
Power	8740 kw

SHELL/UOP PROCESS

Process Description

The Shell Flue Gas Desulfurization Process is a dry metal oxide process based on the ability of copper oxide to react with SO_2 in a flue gas and to be regenerated by hydrogen reducing gas. The end product of the process can be sulfur, SO_2 or sulfuric acid, depending on available markets and other economic considerations. (Figures A5-3 and A5-4).

The adsorption reaction occurs in a set of specially designed, parallel passage, fixed bed reactors according to the following:

$$2CuO + O_2 + 2SO_2 \text{ ---> } 2CuSO_4$$

The reactors operate at about 750°F. Because the process centers around fixed beds that must be regenerated, a swing mode of operation using multiple reactor vessels is employed. When the majority of the copper oxide in an acceptor has been converted to copper sulfate, the 750°F regeneration cycle begins. Hydrogen reducing gas is passed through the vessel. SO_2 is released according to the following reaction:

$$CuSO_4 + 2H_2 \text{ ---> } Cu + SO_2 + 2H_2O$$

Any CuO which is unused during SO_2 adsorption is reduced back to copper:

$$CuO + H_2 \text{ ---> } Cu + H_2O$$

The copper is then regenerated according to the reaction:

$$2Cu + O_2 \text{ ---> } 2CuO$$

Hydrogen for the regeneration step may be generated from a reforming unit or other source. In addition, steam is required for purging the reactors between regeneration and adsorption steps. Any NO_x in the flue gas can be reduced to free nitrogen by injecting a small amount of ammonia into the fixed bed during the adsorption part of the cycle. Over 60 percent of the NO_x can be reduced with an incremental capital cost of 10 percent.

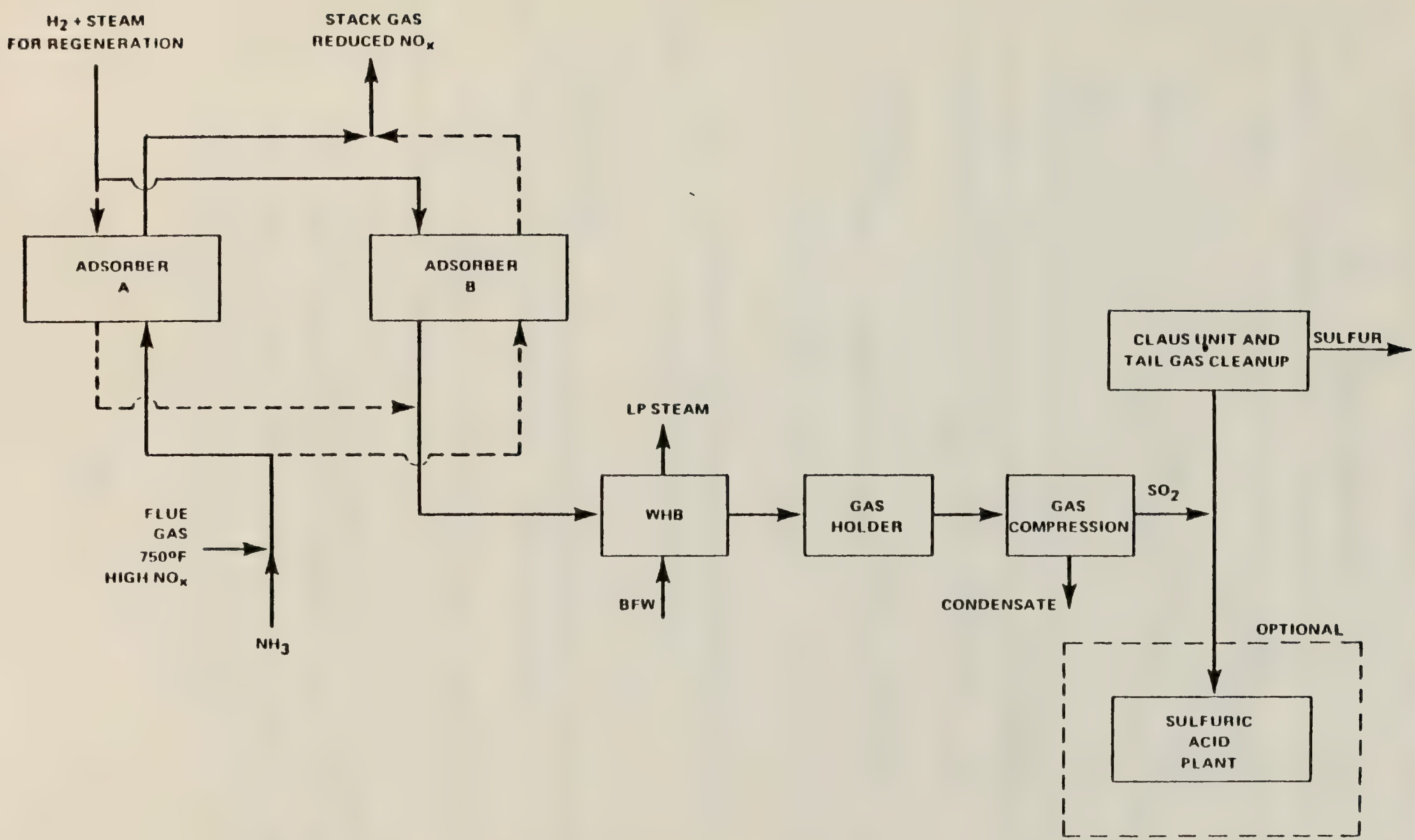


FIGURE A5-3. SHELL U.O.P. PROCESS

FIGURE A5-4

SHELL/UOP PROCESS

SO_2 Absorption

$2CuO + O_2 + 2SO_2 \dashrightarrow 2CuSO_4$

(copper oxide) (copper sulfate)

Regeneration

$CuSO_4 + 2H_2 \dashrightarrow Cu + SO_2 + 2H_2O$

$2Cu + O_2 \dashrightarrow 2CuO$

The SO_2-rich regeneration offgas generates low pressure steam in a waste heat boiler, then is sent to a gas holder to dampen flow surges from the cyclic adsorption system. The gas is compressed and water condensed and separated from the recovered SO_2. The condensed water may be used for boiler feedwater. This gas holder/gas compressor system is less energy intensive than the original design which called for a quench of the SO_2-rich gas stream followed by steam stripping to recover and concentrate the SO_2. This stream is sent to a Claus plant for sulfur production. Tail gas from the Claus unit is recycled to the boiler.

A major design problem with the Shell/UOP Process is the difficulty of integrating the cyclic behavior of the fixed bed adsorption scheme with the variable SO_2 load from the boilers and the relatively inflexible operation of the hydrogen production facility and the Claus plant.

Advantages

1) The process is regenerable, leading to savings in cost of chemicals.

2) Sulfur is recovered as elemental sulfur, sulfuric acid or SO_2.

3) NO_x can be reduced by 60 percent to free nitrogen during the adsorption part of the cycle with the addition of NH_3.

Disadvantages

1) Operating complexity involving integration of swing mode SO_2 acceptor beds with continuous conversion is a potential problem.

2) SO_2 adsorption occurs at 750°F which would require modification of the boiler design or flue gas reheat.

3) SO_2 is oxidized to a metal sulfate and then reduced to both the sulfur and the metal. Theoretically, this requires 4 moles H_2 per mole SO_2 to produce sulfur. Process inefficiencies lead to an actual usage of about 6 moles H_2 per mole SO_2. (This is nearly three times that required by processes that do not oxidize the SO_2 to produce sulfur.)

4) A waste water stream containing dissolved SO_2 is produced.

5) UOP has guaranteed 90 percent SO_2 removal on certain system applications; however, obtaining higher removal efficiencies may be a problem.

Development Status

A commercial-scale unit went on stream in mid-1973 at the SYS (Showa Yokkaichi Sekiyei) Refinery in Japan. This partially integrated unit consists of two adsorbers operating on flue gas from an oil-fired boiler equivalent to about 40 MW of capacity. The longest period of continuous operation has been two months.

A completely integrated unit applied to a coal-fired utility has yet to be built.

Licensor

UOP - Air Correction Division

PROCESS ECONOMIC SUMMARY

DESIGN BASIS:	500 MW, 3.5 percent Sulfur Coal
SO_2 Removal	90 percent
NO_x Removal	70 percent
Waste Stream	40 ppm SO_2 in 185 gpm H_2O

UTILITY AND RAW MATERIAL REQUIREMENTS

Electric Power	10.9 MW
Fuel Oil	40 MM Btu/hr
Steam Credit	29.1 MM Btu/hr
Reducing Agent (H_2)	265 MM Btu/hr
Raw Materials (NH_3)	2,110 lbs/hr

Total Utility and Raw Materials Costs is 3.8 mils/kwh.

Capital costs are not available.

DIAMOX PROCESS

Process Description

In the Diamox process, H_2S is selectively removed from sour gas by countercurrent contacting with an aqueous, ammonia solution (Figure A5-5). In normal sweetening applications, the ammonia concentration in the wash solution is maintained in equilibrium with the ammonia in the gas and therefore practically no ammonia is removed from the gas in the H_2S absorber. The ammonia solution enters the absorber in the range of 100°F, although the lower the operating temperature, the greater the percent of desulfurization.

$$NH_3 + H_2S \rightleftharpoons NH_4^+ + HS^-$$

The rich liquor from the absorber containing dissolved acid gases and NH_3 enters an acid gas stripper after recovering heat from the stripper bottoms solution. In the acid gas stripper, the rich liquor is heated to expel the acid gases; however, ammonia is retained in the liquor due to the temperature and reflux at the top of the stripper. The regenerated solution is cooled and recycled to the H_2S absorber.

The stripped acid gas contains between 6 - 8 volume percent H_2S with the balance being CO_2, with slight amounts of other impurities such as HCN, NH_3 and aromatics. This stream is routed to a Stretford unit for H_2S removal (see Stretford discussion in DEA Process Description.)

Impurities such as thermally stable, soluble thiocyanates and formates accumulate in the circulating solution and will reduce the desulfurization efficiency, causing corrosion, if they are not continuously purged from the system. To prevent the build-up of these impurities, part of the ammonia recycle solution is sent to an ammonia stripper. Ammonia vapor flows overhead and is combined with the sour gas feed. A waste purge stream leaves the bottom of the ammonia stripper. This water will contain organics and ammonia and must be treated further before reuse or disposal.

Advantages

1) The process does not require any chemicals, since the absorption liquor is generated from the ammonia present in the sour gas.

2) Commercial plants have demonstrated a desulfurization efficiency of 97 percent on coke oven gas.

Disadvantages

1) The process will not remove organic sulfur compounds such as carbonyl sulfide (COS) or carbon disulfide (CS_2).

2) Requires a Stretford unit to remove the H_2S from the stripper overhead stream.

3) The technology has been proven commercially only in a coke oven gas application in Japan.

4) The process has a higher capital cost than treating the entire MIS gas stream in a Stretford facility.

5) There is a waste water stream which must undergo treatment.

6) An ammonia absorber would have to follow the Diamox absorber to remove ammonia from the MIS gas.

Commercial Plants

The Diamox process is typically used for treatment of coke oven gases. The first commercial plant went on-stream in early 1974 at Mitsubishi Chemical Industries' Kurosaki Factory and processes about 100,000 NM^3/hr (3.73×10^6 SCFH) of coke oven gas. The largest Diamox plant is a three train unit with a through put capacity of 300,000 NM^3/hr (1.12×10^7 SCFH) of coke oven gas.

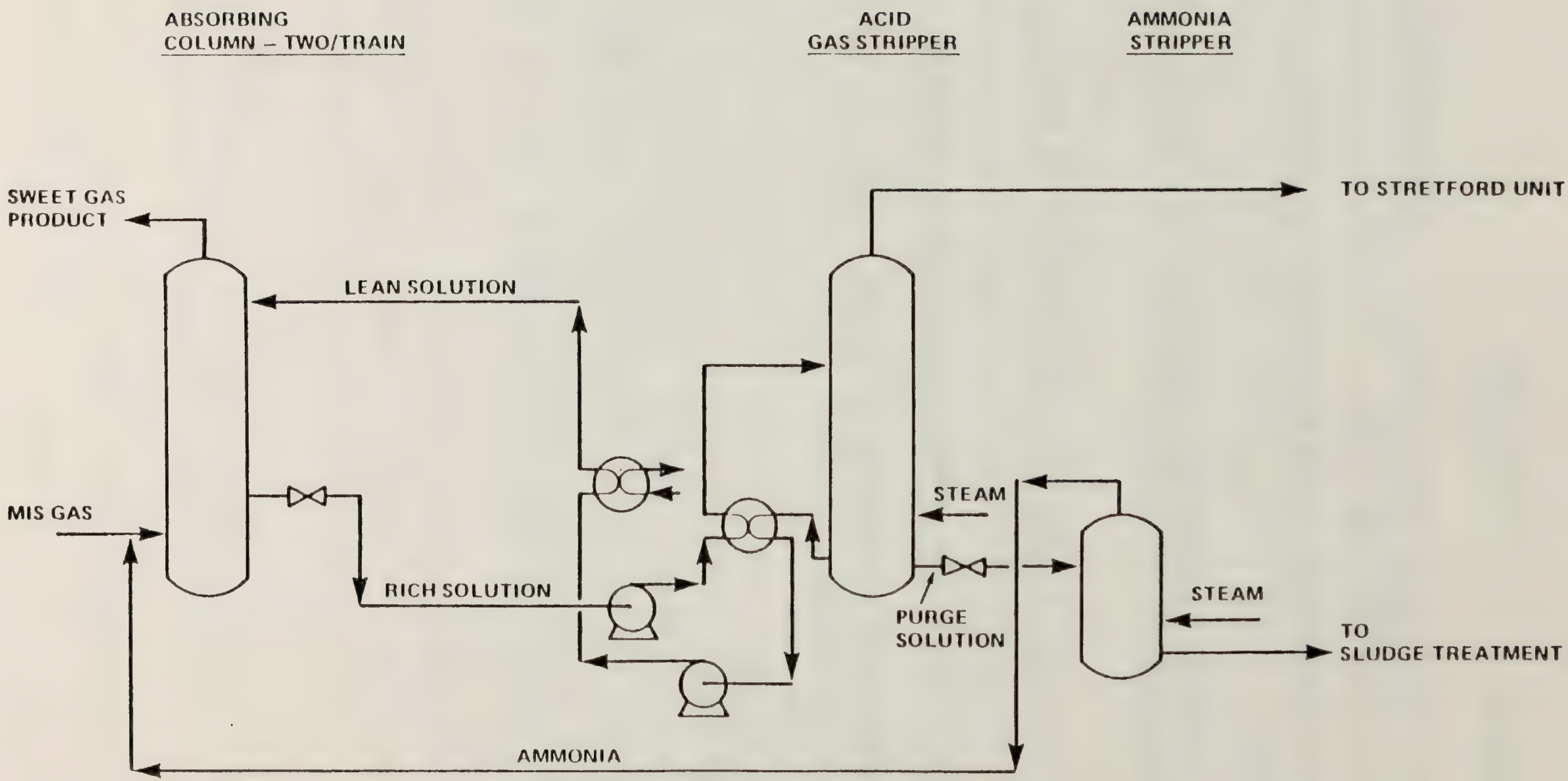


FIGURE A5-5. DIAMOX PROCESS FLOW DIAGRAM

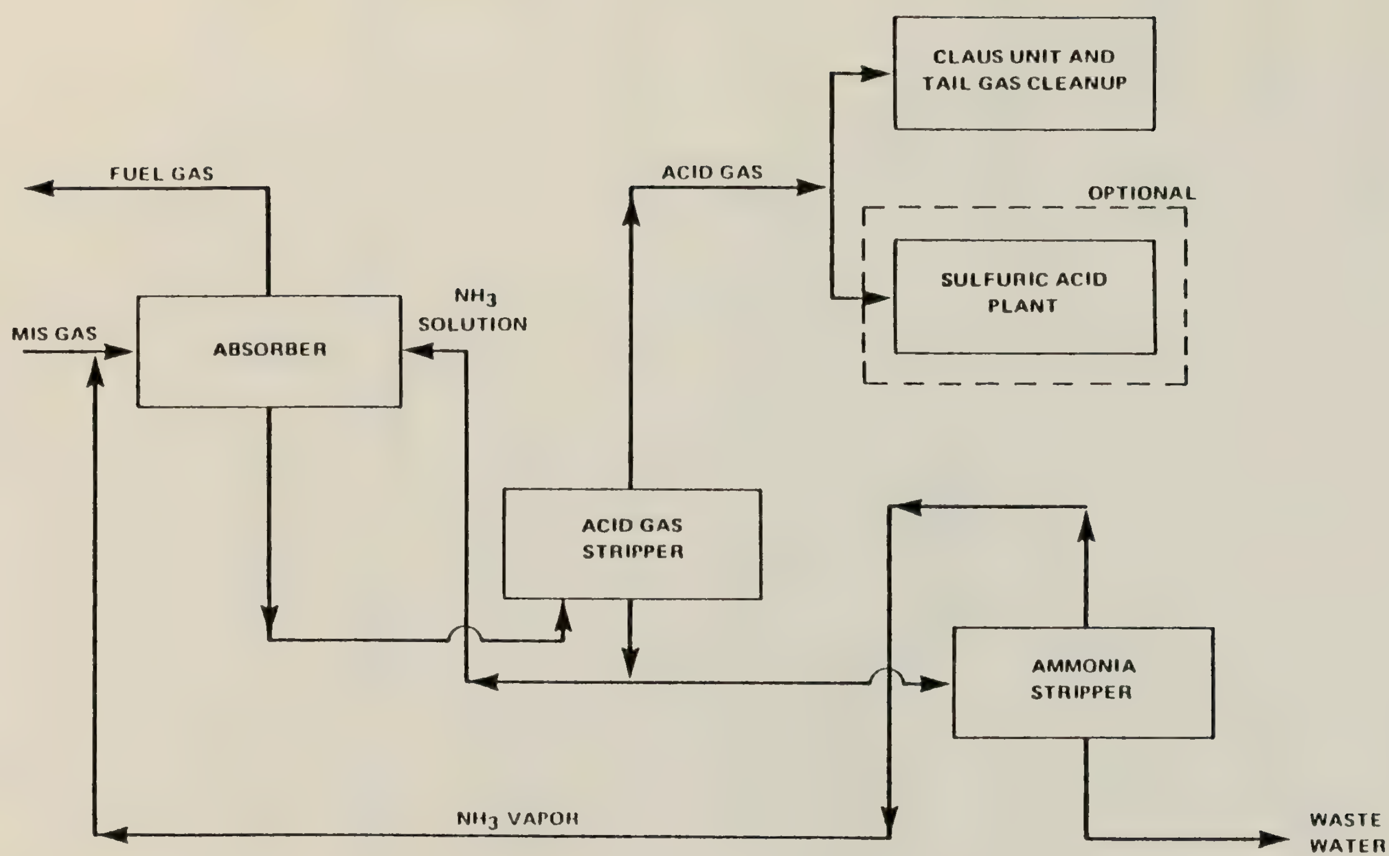


FIGURE A5-6. DIAMOX PROCESS

FIGURE A5-7

DIAMOX PROCESS

H_2S ABSORPTION/REGENERATION

$$NH_3(aq) + H_2S(g) \rightleftarrows NH_4^+(aq) + HS^-(aq)$$

PROCESS ECONOMIC SURVEY (Typical)

Flow Rate	89 MMSCFD of coke oven gas
Inlet Sulfur Concentration	4600 ppm
Sulfur Removal	97 percent
Byproduct Stream	32,000 lbs/day molten sulfur, 99.9 percent purity

UTILITY REQUIREMENTS

Steam, 100 psig	33,000 lbs/hr
Electric Power	1200 kw
Cooling Water, 86°F	4,400 GPM
Boiler Feed Water	22 GPM
Fuel Gas	5.4×10^6 Btu/hr

These utilities include requirements for a Claus unit, but exclude those for a tail gas treatment unit.

Capital costs are unavailable but are 20 percent higher than Stretford according to the Licensor.

RECTISOL PROCESS

The Rectisol Process accomplishes acid-gas removal by physical absorption using cold methanol as the solvent (Figures A5-8 and A5-9). The higher the partial pressure of a sour component, the more readily it is absorbed in the solvent. This characteristic makes the process most applicable to high pressure gas treating where appreciable quantities of sour components are present.

In the first part of the Rectisol Process, precooled gas at a minimum pressure of 250 psig is sent to a prewash contactor where C_4^+ hydrocarbons and water are removed by a small quantity of methanol. The gas proceeds to the second absorption stage where the bulk of the CO_2 and H_2S are washed out with a large quantity of cold methanol. Significant amounts of C_2 and C_3, as well as small amounts of C_1, CO and H_2 are also absorbed. The methanol solution containing H_2S, CO_2 and some hydrocarbons is let down in stages to flash off part of the dissolved components. Most of the dissolved hydrocarbons are recovered and returned to the absorber feed gas.

The methanol solution is flashed further to atmospheric pressure and then sent to a hot stripping section. In this stripping section, an acid gas containing CO_2, H_2S, and some C_1-C_3 is produced. This gas and the gas from the atmospheric flash is sent to Stretford processing units for recovery of elemental sulfur. The Stretford Process offgas containing some hydrocarbons is incinerated.

Since the hydrocarbons removed from the feed gas in the prewash section have boiling points higher than methanol or form azeotropes with it, the straightforward regeneration of the loaded methanol is not possible. Addition of water to the prewash mixture in a decanting vessel brings about a phase separation, with methanol/water as the heavy phase and hydrocarbons as the light phase. Methanol is then easily separated from the water in a steam heated distillation column.

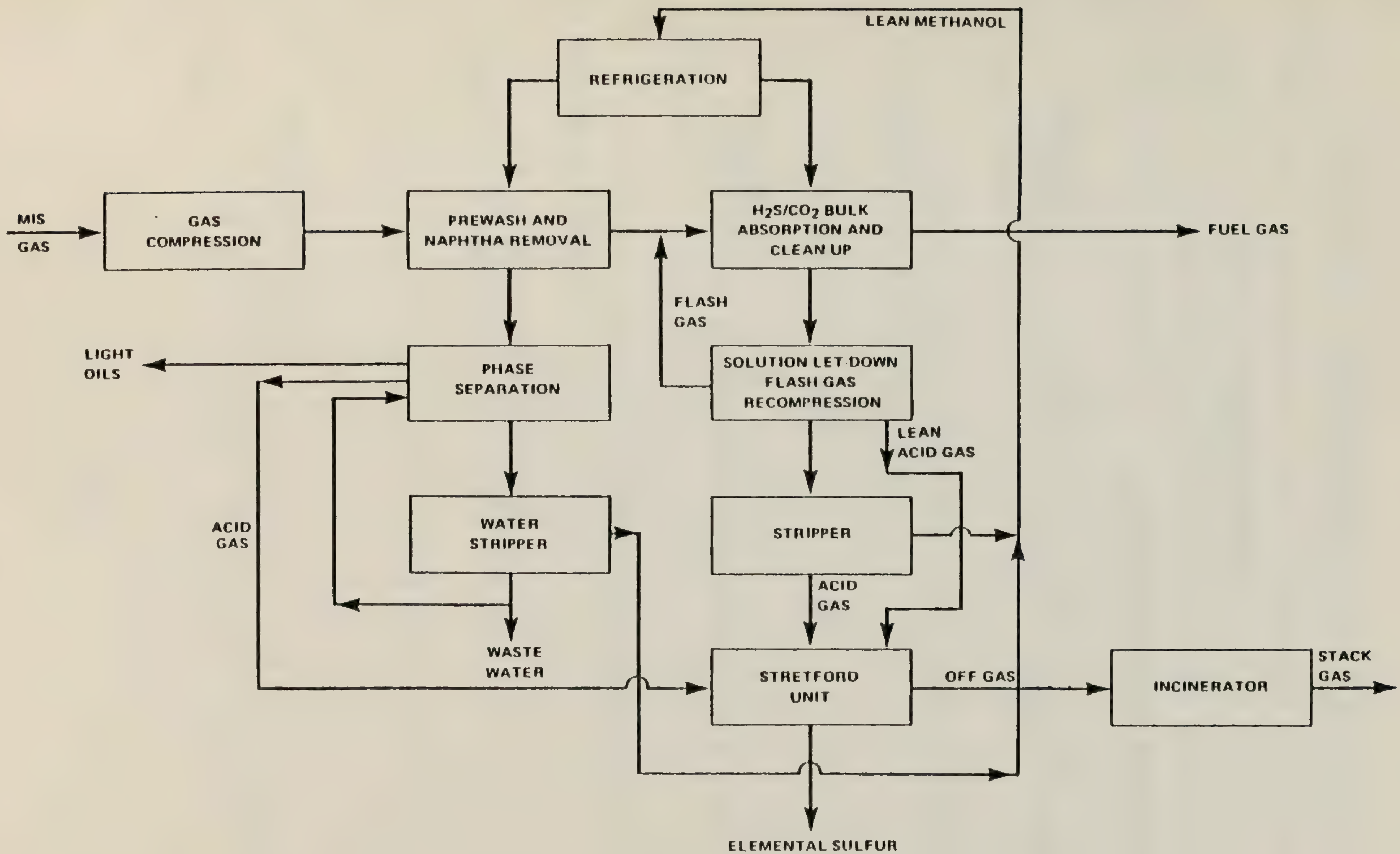


FIGURE A5-8. RECTISOL PROCESS

FIGURE A5-9

RECTISOL PROCESS

Physical Solvent Abosrption/Regeneration

$CH_3OH(l) + H_2S(g) \dashrightarrow CH_3OH(l) + H_2S$ (dissolved)
(Methanol)

An alternative two-stage processing scheme could be used to selectively remove first H_2S and then CO_2. This would produce a concentrated H_2S stream suitable for processing in a Claus unit rather than the more expensive Stretford unit. However, a two-stage Rectisol Process would involve significantly more capital investment and operating expense than the single stage, non- selective scheme and probably more than offset the difference between Claus and Stretford.

Advantages

1) The process is regenerable; waste disposal and reagent costs are greatly reduced.

2) Solvent has a very low freezing point which would be an advantage if the application is in a very cold climate.

3) The process is well proven.

Disadvantages

1) Compression of the feed gas to a pressure over 250 psig would be required.

2) The feed gas must be chilled appreciably (to about -30°C) before entering the contactor.

3) C_3^+ hydrocarbons are absorbed with CO_2 and H_2S and can be recovered only with difficulty.

4) Stretford unit required due to low H_2S concentration in acid gas steam.

Commercial Installation

There are 36 operating Rectisol units and 12 more under construction with a total capacity of 3.6 billion SCFD. Applications have been in the following areas:

1) Removal of CO_2, H_2S, NH_3, HCN and higher hydrocarbons from crude gas produced by coal gasification.

2) Removal of H_2S, COS and CO_2 from gas produced by partial oxidation of hydrocarbons to yield synthesis gas.

3) Integration of gas purification with low temperature plants for the removal of moderate contents of acidic components.

Licensor

Lurgi Kohle und Mineralotechnik GmbH

Linde AG

PROCESS ECONOMIC SUMMARY (Typical Case)

Gas Flow:	118 MM lb/hr acid gas
Pressure:	250 psig
Sulfur Recovery:	99+%

Utility Reguirements:

Power, Shaft	14 MW
Steam 550 psig	215 t/hr

Capital Cost (DFC) = \$73MM

BENFIELD PROCESS

Process Description

The Benfield Process is a chemical solvent process used to absorb CO_2, H_2S and COS from sour gas (Figures A5-10 and A5-11). An aqueous scrubbing solution containing potassium carbonate (K_2CO_3) and special Benfield additives is contacted countercurrently with the sour gas in an absorption column at a pressure of at least 150 psig. The potassium carbonate in solution reacts with the acid gas components to form a "complex" with them:

$$K_2CO_3 + H_2S \rightleftharpoons KHCO_3 + KHS$$

$$K_2CO_3 + CO_2 + H_2O \rightleftharpoons 2KHCO_3$$

At the absorber operating conditions, carbonyl sulfide is hydrolyzed to carbon dioxide and hydrogen disulfide:

$$COS + H_2O \rightleftharpoons CO_2 + H_2S$$

Treated overhead gas can be used as turbine fuel combined cycle power plant.

The absorption solution holds the sour components in a chemically until the temperature of the rich solvent is increased and the pressure is reduced to near atmospheric, at which time the complex is decomposed and the sour gases are released. This regeneration process is accomplished by low pressure steam stripping. The scrubbing solution is recycled to the absorber with makeup solution added for mechanical losses. The recovered sour components are fed to a Claus unit for sulfur production.

The feed gas may be saturated with H_2O and may contain substantial amounts of higher hydrocarbons. In normal applications, acid gas concentrations range from 5 to 50 percent. The temperature of the feed gas, although not critical, is usually in the range of ambient to 400°F. Heat in the feed gas can be used to supply all or part of the process heat requirements. Selective removal of H_2S from CO_2 plus H_2S mixtures producing an H_2S enriched stream can be achieved with modifications to the general Benfield Process scheme. However, this requires considerable additional capital investment and higher operating costs.

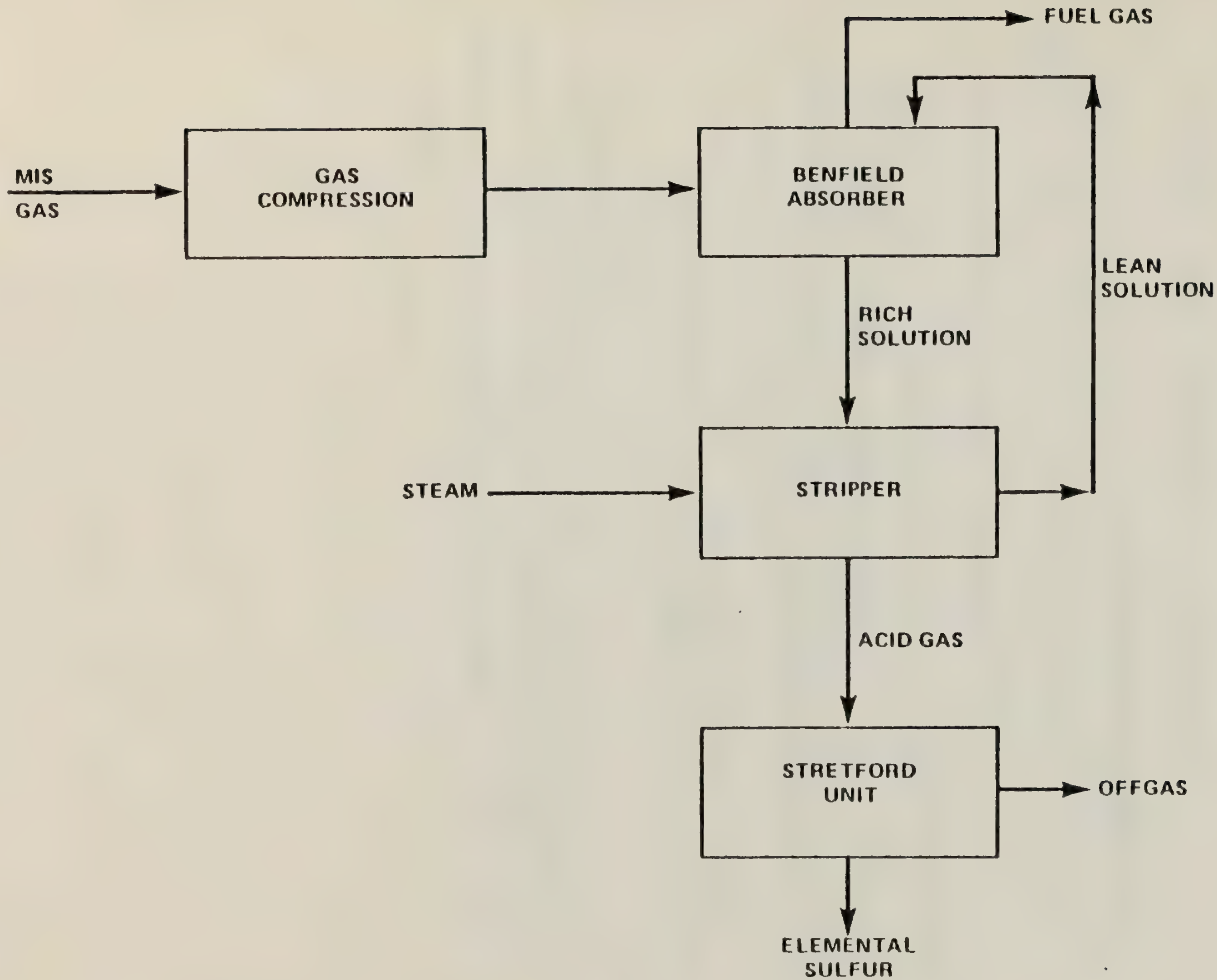


FIGURE A5-10. BENFIELD PROCESS

FIGURE A5-11

BENFIELD PROCESS CHEMISTRY

H_2S Absorption/Regeneration

$$K_2CO_3 + H_2S \underset{\text{REGEN}}{\overset{\text{ABS}}{\rightleftharpoons}} KHCO_3 + KHS$$

(Potassium Carbonate) (Potassium Bicarbonate)

CO_2 Absorption/Regeneration

$$K_2CO_3 + H_2O + CO_2 \underset{\text{REGEN}}{\overset{\text{ABS}}{\rightleftharpoons}} 2KHCO_3$$

Carbonyl Sulfide Hydrolysis

$$COS + H_2O \longrightarrow CO_2 + H_2S$$

Advantages

1) Process is regenerable; waste disposal and reagents costs are reduced.

2) Process can achieve high H_2S and CO_2 removals.

3) Process can selectively remove H_2S or CO_2; however, this is expensive, especially with low H_2S concentrations.

4) Process does not absorb hydrocarbons

Disadvantages

1) Absorber operates at elevated pressures, usually in the range of 150 to 2000 psig. The process is attractive only when the partial pressure of the acidic components is at least 20 psi.

2) The acid gas produced must be treated by a Stretford Process.

Commercial Plants

There are over 450 operating units including 26 units for natural gas sweetening and over 150 units serving substitute natural gas plants for scrubbing of reformed and partial oxidation gases.

Licensor

Benfield Corporation

PROCESS ECONOMIC SUMMARY

Typical Capital Investment (large plant)

$100 per Mscfd of CO_2 + H_2S removed

Typical Operating Utility Requirements

(per Mscf of CO_2 + H_2S required)

Regeneration heat	50,000 - 130,000 Btu
Power (pumping)	1 - 2 Kwh
Total Cooling Duty	50,000 - 100,000 Btu
Chemical Cost	Makeup for mechanical losses only; no degradation

The economics of the Benfield Process are favored by high partial pressure of CO_2 and H_2S. In usual applications, CO_2, or CO_2 and H_2S concentrations range from 5 to 50 percent.

Capital costs and utility requirements given here do not include the equipment and utility costs necessary for compression of feed gas to the absorber pressure.

DRY SCRUBBING

Process Description

Dry scrubbing refers to a group of flue gas desulfurization processes that directly produce a dry product. (Figures A5-12 and A5-13). Usually, one thinks of a baghouse using a dry SO_2 sorbent. Baghouse use is a simple approach in which the sorbent is either applied to the baghouse as a precoat or injected into the flue gas downstream of the boiler. The latter technique is used to increase the residence time of the sorbent in the gas stream. The sorbent is periodically renewed so as to always have adequate reactive species in contact with the flue gas. An alternative approach to increasing the contact time between the sorbent and flue gas is to employ a spray dryer in which a slurry or concentrated sorbent solution contacts the hot flue gas. The heat from the gas evaporates the water and the basic chemical reacts with the SO_2 to form a dry powder. The product is collected by an electrostatic precipitator, cyclones, or baghouses. Baghouses have the advantage of allowing additional contact between flue gas and any unspent sorbent leaving the dryer. The products are captured when the bags are shaken during the normal operating cycle.

Many sorbents have been used, among which are Na_2CO_3, $NaHCO_3$, $NaOH$, $CaCO_3$, and $Ca(OH)_2$. The sorbent reacts with SO_2 forming sulfite salts. Each "caustic" reactant will produce a dry product easily captured by the baghouse.

Dry Sorbent/Baghouse Processes

Advantages

1) The design is simple. The once through approach eliminates recycle streams.

2) The process produces a dry, easy to handle product.

3) The energy requirement is low relative to wet scrubbing processes.

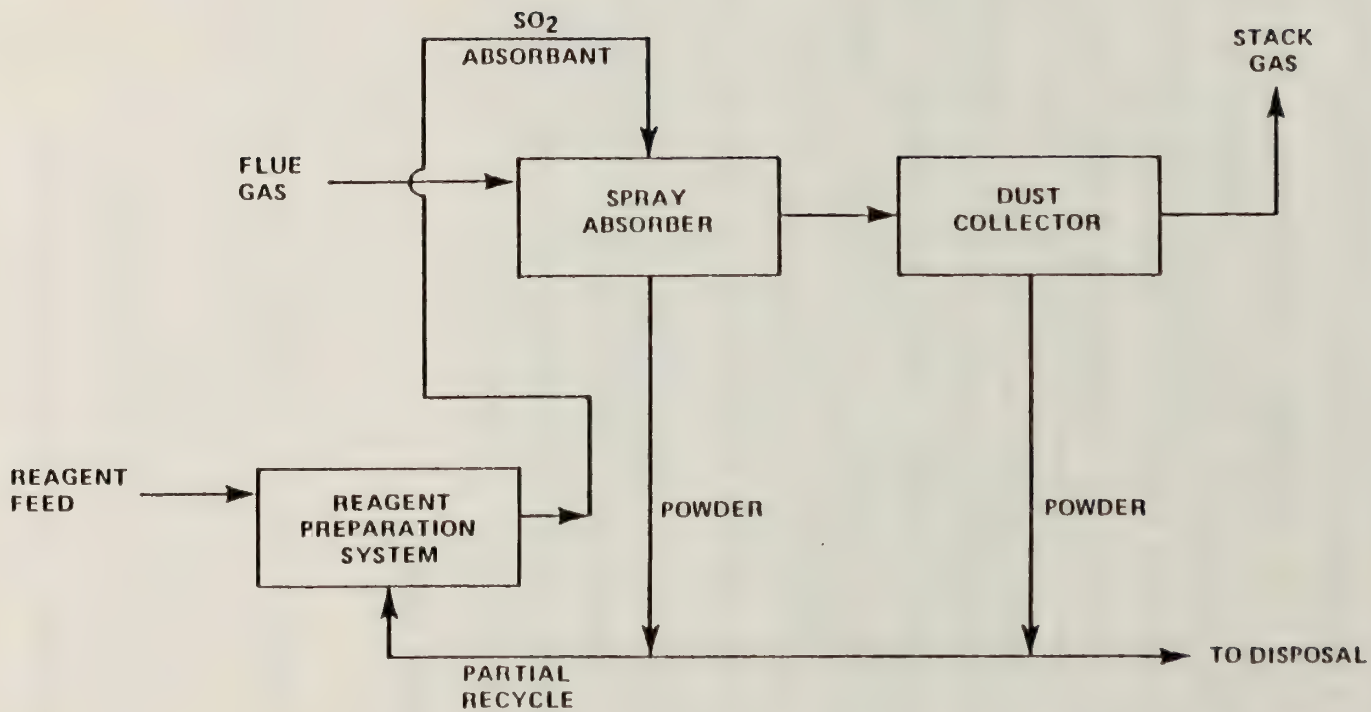


FIGURE A5-12. DRY SCRUBBING PROCESS

FIGURE A5-13

DRY SCRUBBING PROCESSES

Lime	$CaO + SO_2 \text{ ---> } CaSO_3$
Hydrated Lime	$Ca(OH)_2 + SO_2 \text{ ---> } CaSO_3 + H_2O$
Calcium Carbonate	$CaCO_3 + SO_2 \text{ ---> } CaSO_3 + CO_2$
Soda Ash	$Na_2CO_3 + SO_2 \text{ ---> } Na_2SO_3 + CO_2$
Caustic Soda	$2NaOH + SO_2 \text{ ---> } Na_2SO_3 + H_2O$
Sodium Bicarbonate	$NaHCO_3 + SO_2 \text{ ---> } NaHSO_3 + CO_2$

Disadvantages

1) Flue gas must be hotter than usual (500°F, 260°C) in order to achieve SO_2 removal in the range of 90 percent.

2) Sodium based sorbents are the most effective; however, the dry products, Na_2SO_3 and $NaHSO_3$, are water soluble and need to be disposed of in an environmentally acceptable manner.

3) Most studies indicate that high SO_2 removal is only possible at low sorbent utilizations.

Commercial Installations/Development Status

Although no full-scale systems have been sold at this time, sufficient data have been obtained from testing programs to establish cost parameters for these processes. TRW's Environmental Engineering Division has developed a FGD baghouse design for a 500 MW coal-fired utility boiler based on typical utility requirements.

Spray Dryer/Baghouse Processes

Advantages

1) The simple design is easy to operate and maintain.

2) The process produces a dry, easy to handle product.

3) Sorbent residence time is increased over baghouse alone.

4) The process employs the only method of utilizing $CaCO_3/Ca(OH)_2$ in a dry process since these salts are not sufficiently reactive to be used in a baghouose alone.

5) Pilot plant tests report SO_2 removal efficiencies of 90 percent with high sorbent utilization.

Disadvantages

1) The waste product from a sodium based system may require special handling because of the high solubility of sodium sulfite (Na_2SO_3) and sodium sulfate (Na_2SO_4).

2) Flue gas must be hotter than usual (500°F, 260°C) in order to achieve 90 percent removal.

3) SO_2 removal levels of 95% have not been achieved.

Commercial Installations/Development Status

Three full scale spray dryer systems have been sold to date, two in North Dakota and one in Wyoming. The first installations are scheduled to begin operation in mid- to late 1981.

1) Rockwell at Basin Electric's 455 MW Antelope No. 2 (burning 0.68 percent sulfur lignite) will have a once through soda ash (Na_2CO_3) process designed for 62 percent sulfur removal.

2) Western Precipitator at Otter Tail Power's 400 MW Coyote No. 1 (burning 0.9 percent sulfur lignite) will be a lime/limestone system.

3) Babcock & Wilcox at Basin Electric's 500 MW Laramie River Station Unit 3 (burning 0.54 percent sulfur coal). This process will be a lime/limestone system designed to remove 85 percent of the sulfur.

Licensor

None.

PROCESS ECONOMIC SUMMARY

Design Basis: Laramie River Station (500 MW, 0.54 percent sulfur coal)

Gas Flow	1,320,000 SCFM
Inlet SO_2 Concentration	530 PPMV
SO_2 Recovery	85 percent
Capital Cost	$49,807,000 (1981 $)
Chemicals (Lime)	3300 lbs/day
Electric Power	2.451 MW

CITRATE PROCESS

Process Description

The Citrate Process is a regenerable flue gas desulfurization process which uses sodium citrate to absorb SO_2 from flue gas (Figures A5-13 and Figures A5-15). The process can be designed to remove greater than 90 percent of the inlet SO_2. The recovered sulfur species can be converted to elemental sulfur in subsequent processing steps. Several process developers offer versions of this process which differ mainly in absorber configuration, absorber liquor pumping rates, type of buffer, operating pH, methods of H_2S production, and methods of sulfur separation. The basic processing sequence, however, is the same for all and consists of SO_2 absorption, regeneration and sulfur separation, sulfate purge, and H_2S generation.

The Citrate Process employs a water quench to cool the flue gas before it enters the absorber. The gas then enters an absorber where it is scrubbed countercurrently with a solution consisting mainly of sodium citrate, plus a small quantity of sodium sulfate which builds up in the absorber loop. The primary reactions occurring in the absorber are:

$$SO_2 + H_2O \text{ ---> } HSO_3^- + H^+$$

$$H\ Cit^{-2} + H^+ \text{ ---> } H\ Cit^-$$

The lean SO_2 solution enters the tower at a pH of 4.0-5.0 and leaves at a pH of 3.5-4.5. The citrate solution acts as a buffering agent permitting large volumes of SO_2 to be absorbed without a significant reduction in pH. Citric acid [$HOC(CH_2COOH)_2COOH$] and sodium carbonate are added to the absorber feed as necessary to maintain this pH range and a buffer concentration of 0.5 M citrate, respectively.

The SO_2-rich citrate solution is pumped directly to a series of regeneration reactors, where it is contacted countercurrently with an H_2S-rich gas stream. Although process vendors do not agree on the detailed chemistry of the regeneration process, the overall reaction is

$$SO_2\ (\text{liq.}) + 2H_2S \text{ ---> } 3S + 2H_2O$$

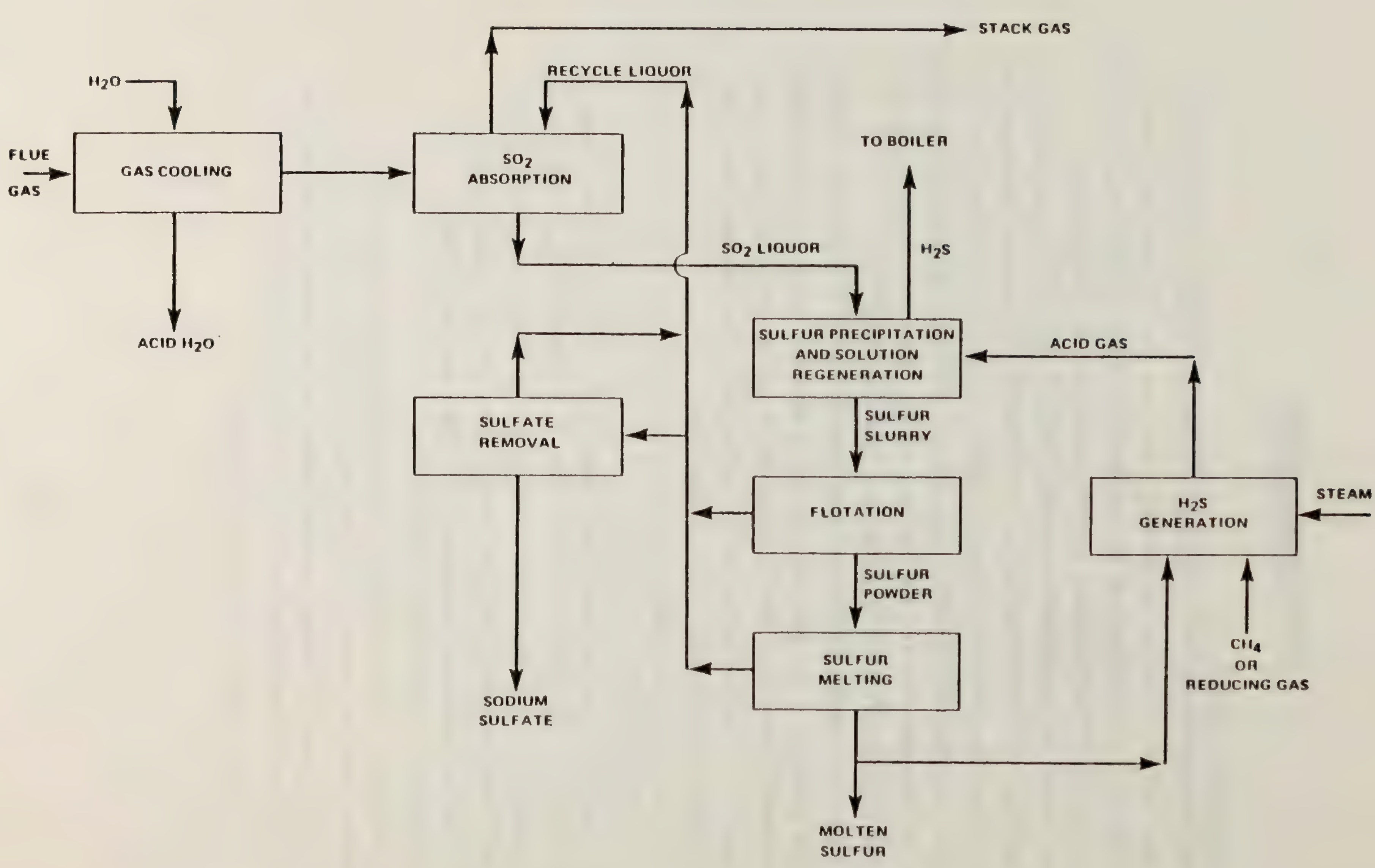


FIGURE A5-14. CITRATE PROCESS

FIGURE A5-15

CITRATE PROCESS

Absorption

$SO_2 + H_2O \text{ ---> } HSO_3^- + H^+$
(bisulfite)

$H\ Cit^{-2} + H^+ \text{ ---> } H_2\ Cit^-$

Regeneration and Sulfur Separation

$SO_2(\text{liq.}) + 2H_2S \text{ ---> } 3S + 2H_2O$

Sulfate Purge

$HSO_3 + 1/2\ O_2 \text{ ---> } HSO_4^-$
(bisulfate)

$3S_2O_3^{-2} + 2H^+ \text{ ---> } 2SO_4^{-2} + H_2O + 4S$
(thiosulfate)

H_2S Generation

$H_2 + S \text{ ---> } H_2S$

The product gas has an H_2S to SO_2 mole ratio of 2.06 to 1 providing 3 percent H_2S above stoichimetric requirements. The excess H_2S-rich gas out of the last reactor is vented to the boiler. The sulfur slurry out of the last regeneration reactor is pumped to a sulfur flotation unit where the sulfur is separated from the citrate liquor by kerosene or air flotation. The buffered solution, essentially free of elemental sulfur, is recycled to the absorber feed, and the sulfur slurry is continuously removed from the flotation cell. The slurry then passes through a melter and a decanter for final separation of molten sulfur from the regenerated citrate liquor. Product molten sulfur for disposal or sale accounts for 1/3 of the sulfur produced, while 2/3 of the molten sulfur is recycled for H_2S production.

The sulfate purge system for the Citrate Process is based on an assumed oxidation of absorbed sulfur dioxide ranging from about 1-4 percent. The purge system could operate intermittently whenever analysis indicated high levels of sulfate in the solution or on a continuous basis if desired. The sulfates are formed according to the following reactions:

$$HSO_3^- + 1/2\ O_2 \dashrightarrow HSO_4^-$$
$$3S_2O_3^{-2} + 2H \dashrightarrow 2SO_4^{-2} + H_2O + 4S$$

Sodium sulfate is removed from the citrate solution by crystallization. The solution is vacuum crystallized, centrifuged, melted to redissolve the hydrated sodium sulfate, recrystallized, and dried to anhydrous sodium sulfate.

The external generation of H_2S is a unique feature of the Citrate Process. Reducing gas or commercially pure hydrogen is reacted with 2/3 of the product sulfur to form H_2S for use in the regeneration step. Since the regeneration reactor operates at a much lower temperature than the H_2S generation step and unreacted sulfur vapors will condense upon cooling, care must be taken to prevent plugging of the gas lines by condensed sulfur. Several methods have been proposed for handling this problem.

Advantages

1) Over 95 percent SO_2 removal efficiencies are possible.

2) Process is regenerable; sodium sulfate and sulfur produced as by-products.

Disadvantages

1) Unknown aspects of the process chemistry present a potential limitation to scale-up of the regeneration reactors.

2) Precipitation or condensation of sulfur in various parts of the system lead to plugging.

3) Low service factors.

4) Uncertainties lie in the use of reducing gas to generate H_2S.

5) Scale-up has not been demonstrated for the kerosene addition separation system.

6) A potential hydrocarbon emission problem exists with the use of kerosene in the sulfur flotation unit.

7) High capital and operation costs for the regeneration section relative to other wet regenerable processes.

Commercial Installations/Development Status

The U.S. Bureau of Mines pioneered the development of the Citrate Process with development work also being done by Arthur G. McKee and Co., Peabody Engineering, and Pfizer, Inc. No commercial installations exist at this time. The Bureau of Mines has operated a 0.5 MW pilot plant since 1974 at the Bunker Hill Lead Smelter in Kellogg, Idaho. The feed gas to the pilot plant was 1000 SCFM with 0.5 percent SO_2. Consistent SO_2 removal efficiencies of 96-99 percent were obtained. The longest continuous run was 30 days. A 1 MW pilot plant was operated by McKee, Peabody, and Pfizer in 1974. The feed gas was 2000 SCFM of flue gas containing 1000-2000 ppm SO_2. Although consistent SO_2 removal efficiencies of 95-97 percent were attained; the longest sustained run was 180 hours. A 60 MW demonstration plant is currently under construction at the St. Joe Zinc Co. power plant in Monaca, Pennsylvania. The plant will treat 456,000 SCFM of gas with 1900 ppm SO_2.

Licensor

None.

Economics

Utility and raw material requirements for the Citrate Process have been determined; the total annual costs in 1976 dollars are $3.8 MM. This value is for a 500 MW coal-fired boiler in which the feed coal contains 3.5 weight percent sulfur. The percent SO_2 removal in the system was not quoted.

MAGNESIA WET SCRUBBING PROCESS

Process Description

The Magnesia Wet Scrubbing Process uses magnesium oxide to absorb SO_2 in a wet scrubber (Figures A5-16 and A5-17). The aqueous slurry of magnesium sulfite formed in the scrubber is dried and calcined to regenerate magnesium oxide and produce an SO_2-rich gas stream. This gas stream can be used to produce sulfuric acid or elemental sulfur. Sulfur dioxide removal efficiencies of over 90 percent have been demonstrated. The basic Magnesia Scrubbing process consists of four major sections: SO_2 absorption, $MgSO_3/MgSO_4$ separation and drying, MgO regeneration and SO_2 recovery, and sulfur production.

An aqueous slurry of magnesium hydroxide and magnesium sulfite (pH range 6.5-8.5) is used to absorb the SO_2 according to

$$Mg(OH)_2 + SO_2 \text{ ---> } MgSO_3 + H_2O$$
$$MgSO_3 + H_2O + SO_2 \text{ ---> } Mg(HSO_3)_2$$

Sulfite oxidation gives rise to sulfates by the following reaction:

$$MgSO_3 + 6H_2O \text{ ---> } MgSO_3 \cdot 6H_2O$$
$$MgSO_3 + 3H_2O \text{ ---> } MgSO_3 \cdot 3H_2O$$
$$MgSO_4 + 7H_2O \text{ ---> } MgSO_4 \cdot 7H_2O$$

The bisulfite in the spent scrubbing liquor is reacted with magnesium hydroxide which is formed by slaking the magnesium oxide in the fresh magnesium oxide slurry stream:

$$MgO + H_2O \text{ ---> } Mg(OH)_2$$
$$Mg(OH)_2 + Mg(HSO_3)_2 + 4H_2O \text{ ---> } 2(MgSO_3 \cdot 3H_2O)$$

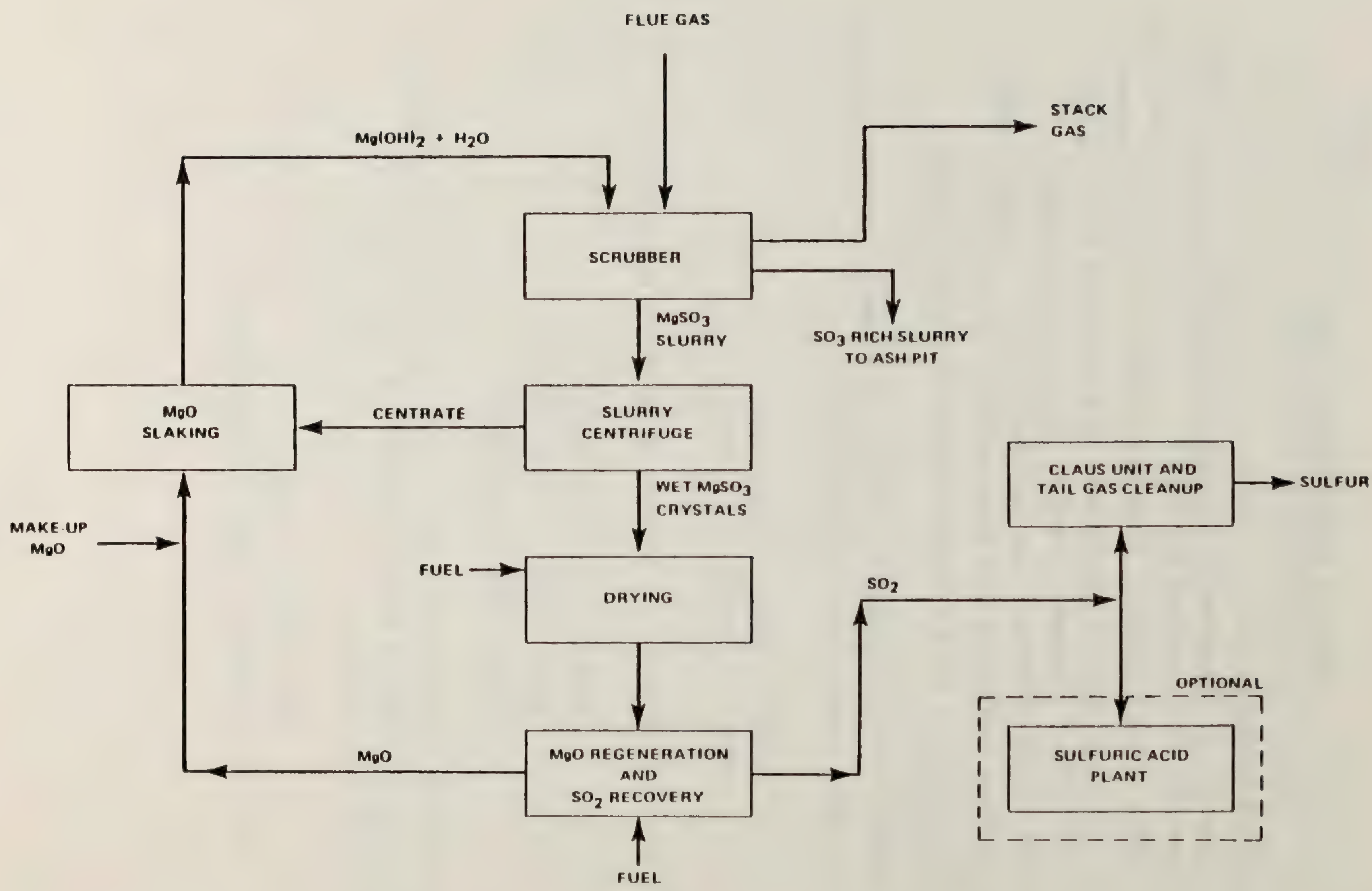


FIGURE A5-16. MAGNESIA WET SCRUBBING PROCESS

FIGURE A5-17

MAGNESIA WET SCRUBBING PROCESS

Absorption

$Mg(OH)_2 + SO_2$ --- $MgSO_3 + H_2O$

$Mg(SO_3) + H_2O + SO_2$ --- $Mg(HSO_3)_2$

$Mg(SO_3) + 1/2\ H_2O$ ---$MgSO_4 + H_2$

$MgSO_3/MgSO_4$ Separation and Drying

$Mg(SO_3) + 6H_2O$ ---> $MgSO_3 \cdot 6H_2O(2)$

$Mg(SO_3) + 3H_2O$ ---> $MgSO_3 \cdot 3H_2O(s)$

$MgSO_4 + 7H_2O$ ---> $MgSO_4 \cdot 7H_2O(s)$

MgO Regeneration and SO_2 Recovery

$MgSO_3$ ---> $MgO + SO_2$

$MgSO_4 + 1/2\ C$ ---> $MgO + SO_2 + 1/2\ CO_2$

Regeneration of Scrubbing Liquor

$MgO + H_2O$ ---> $Mg(OH)_2$

$Mg(OH)_2 + Mg(HSO_3)_2 + 4H_2O$ ---> $2(MgSO_3 \cdot 3H_2O)$

After absorption of SO_2 in the scrubber, a portion of the slurry from the main scrubber circulation loop is removed and sent to a centrifuge, where 50 percent of the incoming solids are separated. The wet solids then go to a dryer and are dried by combustion gases from an oil burner.

The dried $MgSO_3/MgSO_4$ solids are heated in an oil-fired rotary kiln or fluidized bed reactor to decomposition as shown below:

$$MgSO_3 \dashrightarrow MgO + SO_2$$

The $MgSO_4$ is also reduced in this calciner using carbon as a reducing agent:

$$MgSO_4 + 1/2\ C \dashrightarrow MgO + SO_2 + 1/2\ CO_2$$

The MgO is then recycled to the absorption recycle loop. The sulfur dioxide-rich gas from the calciner is piped to either a sulfur or sulfuric acid production unit.

Advantages

1) Process is regenerable; waste disposal and reagent costs are greatly reduced.

2) The central regeneration facility could serve several FGD scrubber facilities.

Disadvantages

1) High energy costs required due to drying and thermal regeneration steps.

2) High L/G ratio required.

3) The centrifuge is a problem area.

4) A separate chemical or acid plant is required for SO_2 recovery.

5) The process would utilize only a small amount of briny water in the quench section.

Commercial Installations/Development Status

The Magnesia Wet Scrubbing Process has been proven to be feasible on a demonstration scale. The scrubbing units are typically designed for 90 percent SO_2 removal. Three Japanese units (25-160 MW) have shown an SO_2 recovery of over 90 percent. Three 950-150 MW retrofit pilot units in the U.S. have demonstrated 90 percent SO_2 recovery on both oil-fired and coal-fired boilers. The units in the U. S., however, have suffered from low system reliability.

Licensor

United Engineers & Constructors, Inc.

Economics

Utility and raw material requirements for the Magnesia Wet Scrubbing Process have been determined with both sulfur and sulfuric acid production. The annual utility and raw material costs in 1976 dollars are $6.1 MM for the sulfur production case, and $3.3 MM for the sulfuric acid production case. These values correspond to 90 percent SO_2 removal of the gas from a 500 MW coalfired boiler. The coal feed to the system contains 3.5 weight percent sulfur.

SODA ASH SCRUBBING PROCESS

Process Description

The Soda Ash Scrubbing Process utilizes an aqueous sodium carbonate solution to absorb sulfur dioxide from flue gas (Figures A5-18 and A5-19). Also known as the Aqueous Carbonate Process (ACP), the process can remove 90-95 percent of the SO_2 in the flue gas streams from coal-fired power plants. The dry scrubber product is treated to regenerate the scrubbing solution and to produce elemental sulfur. Two features unique to this process are: (1) the use of a spray dryer as an SO_2 scrubber (this produces a dry, granular salt mixture suitable for regeneration); and (2) complete reduction of the sodium salts in a molten pool. The technology for the regeneration and sulfur production steps is based upon established practices in the pulp and paper and chemical industries. The process can be divided into five sections: gas cleaning, reduction, quenching and filtration, carbonation, and sulfur production.

The SO_2 scrubbing and product collection equipment is combined in the gas cleaning section. This employs a spray dryer for SO_2 scrubbing and a bank of cyclones in series with an electrostatic precipitator for product collection and final particulate removal from the gas stream.

Flue gas enters the spray dryer scrubber at temperatures typically between 250° and 350°F. Care must be taken to insure the gas remains above the dewpoint temperature to prevent condensation. Here the gas is contacted with atomized droplets of Na_2SO_3 solution. These droplets are typically generated by high speed centrifugal atomizers and driven outward, in crossflow to the flue gas.

In the scrubber, gaseous SO_2 is absorbed into the liquor where it reacts with Na_2CO_3 to form sodium sulfite (Na_2SO_3) as shown below:

$$SO_2(g) + Na_2CO_3(aq) \longrightarrow Na_2SO_3(aq) + CO_2(g)$$

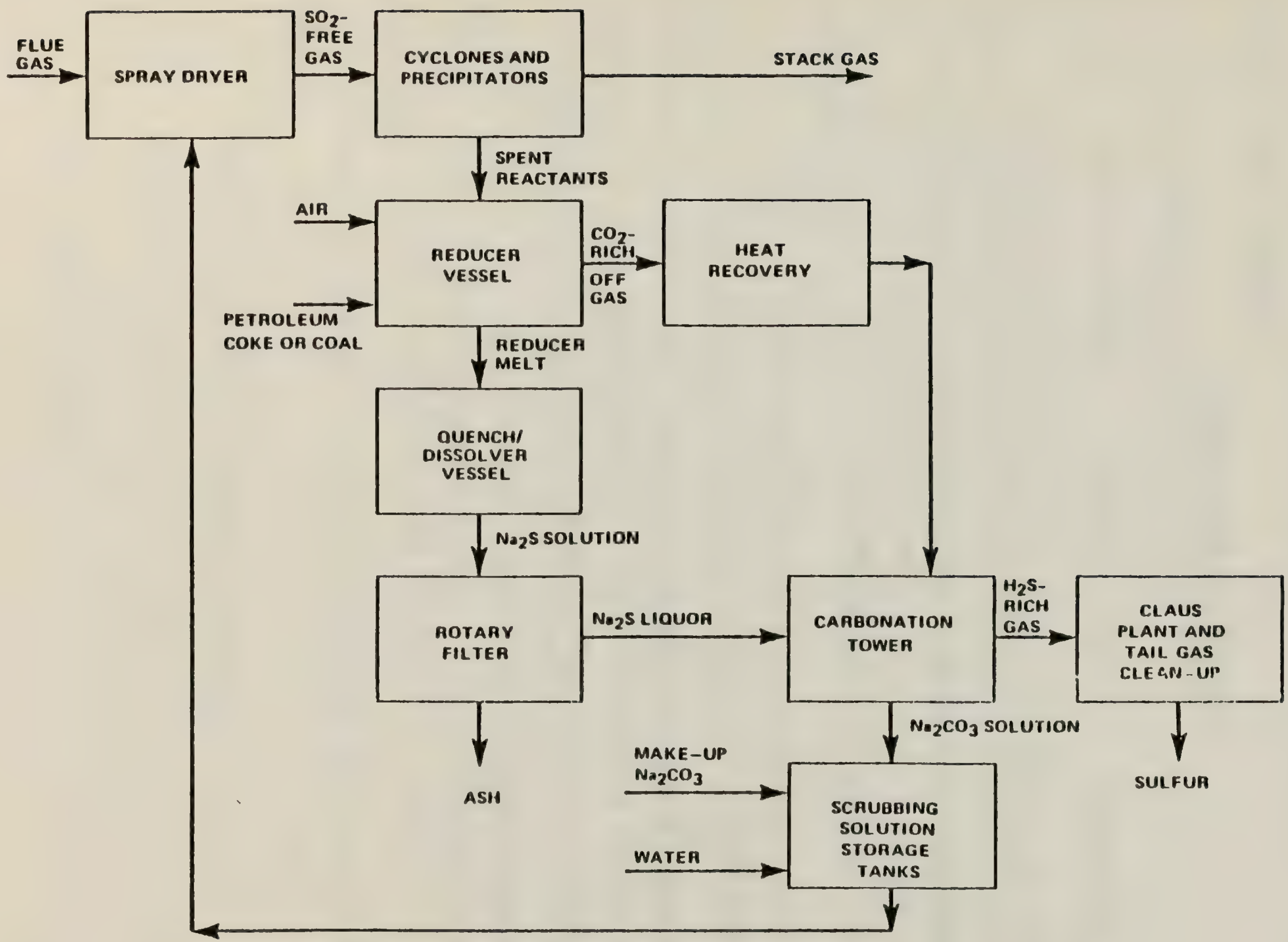


FIGURE A5-18. SODA ASH SCRUBBING PROCESS

FIGURE A5-19

SODA ASH SCRUBBING PROCESS

Gas Cleaning

$$SO_2 + Na_2CO_3(aq) \text{ ---> } Na_2SO_3(aq) + CO_2$$

$$Na_2SO_3(aq + s) + 1/2\ O_2 \text{ ---> } Na_2SO_4(aq + s)$$

$$SO_3 + Na_2CO_3(s) \text{ ---> } Na_2SO_4(s) + CO_2$$

Reduction

$$Na_2SO_3(l) + 3/2C \text{ ---> } Na_2S(l) + 3/2CO_2$$

$$Na_2SO_4(l) + 2C \text{ ---> } Na_2S(l) + 2CO_2$$

$$C + O_2 \text{ ---> } CO_2$$

In addition to this primary reaction the following reactions produce sodium sulfate (Na_2SO_4):

$$Na_2SO_3(aq + s) + 1/2\ O_2 \text{ ---> } Na_2SO_4(aq + s)$$

$$SO_3(g) + Na_2CO_3(s) \text{ ---> } Na_2SO_4(s) + CO_2(g)$$

The product mixture formed by these reactions is usually about 60 percent sulfite, 20 percent sulfate, and 20 percent unreacted carbonate, by weight. Typical liquid-to-gas (L/G) ratios for this operation are near 0.3 gal/1,000 scf. Because of the low liquid rate, insufficient water is present in the scrubber to saturate the gas, so that the spent reactant is entrained as dry particles.

Sulfur dioxide-clean flue gas exits the spray dryer and is routed to a bank of product collection cyclones, where the majority of the dry particles are removed. Final particulate removal is accomplished in high efficiency electrostatic precipitators in which particulate emissions are limited to 0.01 grain/ scf or less. Spent reactants from both the cyclones and precipitator are collected and sent to the reduction section.

The dry product collected in the gas cleaning system is sent to the reducer vessel. This vessel contains a pool of molten salts at temperatures between 1700° and 1900°F. Carbon is injected in the form of petroleum coke or coal. Combustion air is bubbled through the melt from injection nozzles in the vessel walls.

In the molten salt pool, the following reactions are known to take place:

$$Na_2SO_3(l) + 3/2C(s) \text{ ---> } Na_2S(l) + 3/2CO_2(g)$$

$$Na_2SO_4(l) + 2C(s) \text{ ---> } Na_2S(l) + 2CO_2(g)$$

$$C(s) + O_2(g) \text{ ---> } CO_2(g)$$

The first two reactions are endothermic. The third is exothermic, however, and provides heat for both the endothermic reactions and system heat losses. The mechanism for this last reaction is complex, involving sequential oxidation-reduction of the sulfur-containing salts as well as direct oxidation of carbon.

The CO_2-rich offgas from the reducer is sent to the carbonation section after passing through the recuperator, waste heat boiler, and gas cooling tower. Reducer melt is continuously withdrawn and directed to the quench/dissolver vessel.

The sodium sulfide melt from the reducer is dispersed into fine droplets by steam shatter jets and dissolved in solution near its boiling point. Insoluble material, mostly fly ash and unreacted coke, is filtered out at this point using a rotary drum vacuum filter. Sodium is recovered from the ash filter cake using a simple washing technique. Both the quench and filtration operations are considered proven technology in the pulp and paper industry.

After the quench-filtration step, the sodium sulfide liquor is contacted with CO_2-rich reducer offgas in a series of carbonation towers. The technology for this process step has been developed in the pulp and paper industry and proven processes are available. The originator of the soda ash process, Atomics International, is currently developing their own carbonation scheme by modifying existing technology. The details of their carbonation process are proprietary. The process reacts the CO_2-rich reducer offgas and the sodium sulfide liquor from the ash filter, and produces a concentrated Na_2CO_3 solution for recycle to the gas cleaning subsystem plus an H_2S-rich Claus plant feed gas.

The H_2S produced in the carbonation section is directed to a Claus plant for conversion to elemental sulfur. Claus technology is commercially available but has not been tested for specific application with this desulfurization process. The Claus plant tail gas is combusted and returned to the spray dryer for treatment.

The spray dryer and the molten salt reactor are two important design areas. The key to reliable operation of the spray dryer is efficient atomization of the scrubbing solution.

Control of spray dryer operations is important as too much water can cause condensation downstream and too little water will lower the efficiency of the atomizers and hence reduce the ability to remove SO_2. Operation of

molten salt beds in reducing atmospheres has historically been a difficult process operation. The developer feels that operating problems are likely to occur in the future in this process area.

The design of the molten salt reducer is a rather complex problem. Attempts to characterize the kinetics of the reduction reaction have not been successful as the reaction goes to completion before a sample can be analyzed. At the present time, a rather conservative approach to scale-up of this vessel has been adopted. Petroleum coke is used as the carbon source in the reducer. The use of coal as a carbon source would be desirable, but other design problems as yet undefined could arise due to increased amounts of fly ash, chloride, and trace contaminants.

Advantages

1) The technology has been proven in the pulp and paper industry.

2) The SO_3 removal is high, at least 95 percent.

3) The contact solution is clear, not a slurry.

Disadvantages

1) Soda ash, the reagent, is quite expensive and operating costs are quite high.

2) A Claus sulfur recovery unit is required.

3) The process has not been demonstrated commercially.

Commercial Installations/Development Status

An entire soda ash scrubbing system has not been operated in integrated fashion even on a pilot scale. All of the processing steps, however, have either been tested on a 1000 SCFM scale or are considered proven technology by the developer. It is not known whether contaminants from one area will present operational problems in another.

Licensor

Atomics International.

Economics

Raw material and utility costs have been estimated for soda ash scrubbing of the flue gas from a 500 MW coal-fired unit operating on coal with 3.5 weight percent sulfur content. The total costs were estimated to be $3.21 MM.

AMMONIA SCRUBBING PROCESS

Process Description

The Ammonia Scrubbing Process is a regenerable process which removes SO_2 by absorption in an aqueous ammonium sulfite ($[NH_4]_2SO_3$) and ammonium bisulfite (NH_4HSO_3) solution (Figures A5-2- and A5-21). First the flue gas flows through a prewash section upstream of the absorber where the gas is cooled with water to its adiabatic saturation temperature. The prewash section operates with an independent water loop. The prewashed flue gas then flows to a staged absorber where it is contacted countercurrently with the scrubbing solution to effectively absorb SO_2 and form ammonium bisulfite.

$$SO_2 + (NH_4)_2SO_3 + H_2 \text{ ---> } 2NH_4HSO_3$$

Other reactions occurring in the absorber are given by the following:

$$NH_4HSO_3 + NH_3 \text{ ---> } (NH_4)_2SO_3$$

$$SO_3 + (NH_4)_2SO_3 \text{ ---> } (NH_4)_2SO_4 + SO_2$$

$$O_2 + 2(NH_4)_2SO3 \text{ ---> } 2(NH_4)_2SO_4$$

A staged absorber is used to produce an outlet liquor with the high ammonium salt concentration necessary for regeneration while maintaining low salt concentrations on the final stage to reduce ammonia losses and the potential formation of an ammonium salt plume. A water wash after the top stage can be used to further reduce ammonia losses. This process can be designed with an SO_2 removal efficiency of up to 99 percent by adding absorber stages. The clean gas is reheated to 175°F with steam before it is exhausted.

The product liquor from the bottom stage of the absorber is fed to the acidulator where ammonium bisulfate (NH_4HSO_4) reacts with the liquor to release SO_2:

$$NH_4HSO_3 + NH_4HSO_4 \text{ ---> } (NH_4)_2SO_4 + H_2O + SO_2$$

$$(NH_4)_2SO_3 + 2NH_4HSO_4 \longrightarrow 2(NH_4)_2SO_4 + H_2O + SO_2$$

A slight excess of bisulfite is metered to the acidulator to insure complete reaction of the ammonium ions in the liquor.

The liquor is subsequently stripped with either air or steam to remove all of the remaining free SO_2. The SO_2 gas stream produced by the acidulator and stripper is approximately 65 percent SO_2 and is a suitable feed for a sulfuric acid plant or a Claus unit. The acidulated, stripped liquor is heated to about 170°F and fed to the crystallization and separation section where water is evaporated and ammonium sulfate crystals are produced. The evaporated water is condensed and recycled to the absorber along with any offgas generated. The ammonium sulfate crystals are dewatered, dried, and sent to a decomposer designed to thermally disassociate the ammonium sulfate to ammonium bisulfate and NH_3 at about 700°F:

$$(NH_4)_2SO_4 \longrightarrow NH_3 + NH_4HSO_4$$

Approximately 85 percent decomposition is accomplished. The ammonium bisulfate is fed to the acidulator. The offgas is condensed with the ammonia subsequently stripped out and absorbed in an ammonia absorber for recycle to the absorption section.

The quantity of sulfate crystals produced is in excess of that required to feed the thermal decomposer so that a net by-product of ammonium sulfate results. This stream should be relatively pure and may be marketed as fertilizer.

Advantages

1) Most of the ammonia produced in the MIS process could be consumed in a raw form to produce $(NH_4)_2SO_4$, thus reducing the cost of the ammonia recovery process.

2) The process makes an acidic fertilizer that is suited for Western soils.

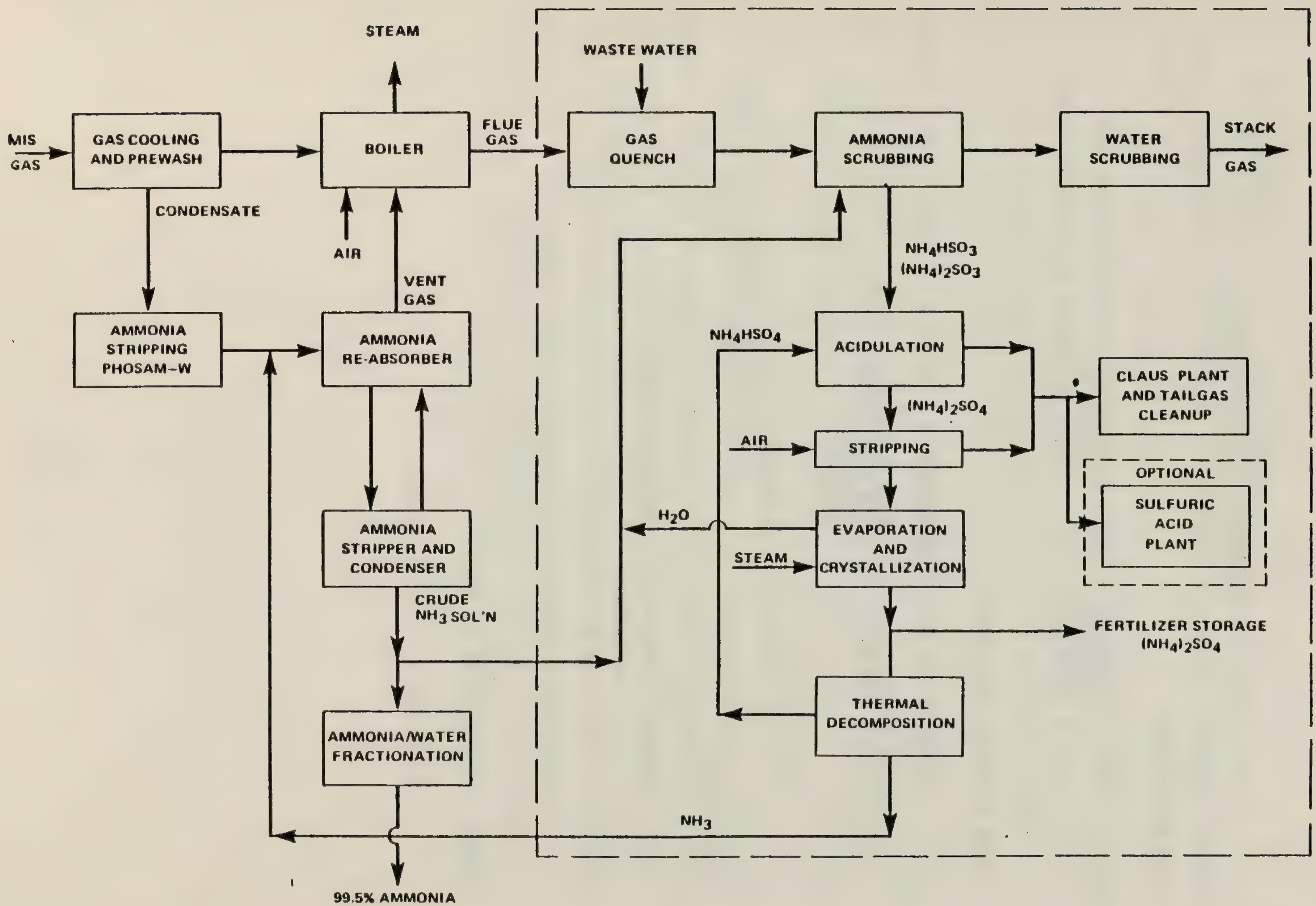


FIGURE A5-20. AMMONIA SCRUBBING PROCESS

FIGURE A5-21
AMMONIA SCRUBBING PROCESS

SO_2 ABSORPTION:

$$SO_2 + \underset{\text{(AMMONIUM SULFITE)}}{(NH_4)_2SO_3} + H_2O \text{ ---> } \underset{\text{(AMMONIUM BISULFITE)}}{2NH_4HSO_3}$$

OTHER ABSORBER REACTIONS:

$$NH_4HSO_3 + NH_3 \text{ ---> } (NH_4)_2SO_3$$

$$SO_3 + (NH_4)_2SO_3 \text{ ---> } \underset{\text{(AMMONIUM SULFATE)}}{(NH_4)_2SO_4} + SO_2$$

$$O_2 + 2(NH_4)_2SO_3 \text{ ---> } 2(NH_4)_2SO_4$$

ACIDULATION

$$NH_4HSO_3 + \underset{\text{(AMMONIUM BISULFATE)}}{NH_4HSO_4} \text{ ---> } (NH_4)_2SO_4 + H_2O + SO_2$$

$$(NH_4)_2SO_3 + 2NH_4HSO_4 \text{ ---> } 2(NH_4)_2SO_4 + H_2O + SO_2$$

THERMAL DECOMPOSITION (@ 700°F)

$$(NH_4)_2SO_4 \text{ ---> } NH_3 + NH_4HSO_4$$

Disadvantages

1) The process would be attractive if a market for $(NH_4)_2SO_4$ exists. Otherwise, it will consume valuable ammonia while creating a disposal problem.

2) The potential formation of an ammonium salt plume is an environmental consideration unique to ammonia processes. The discharge of a plume, particularly one that eventually oxidizes to very fine ammonium sulfate particles, is a serious process liability.

Note: Further study is being done with respect to the above noted disadvantages. If the study should prove to remove or diminish the noted disadvantages, this process could be one of the processes of choice for SO_2 control.

Commercial Plant/Development Status

TVA has operated a 1.2 MW pilot plant on a slipstream from a coal-fired boiler since 1968; the facility, however, is not totally integrated. The technical feasibility of the individual unit operations of this process has been demonstrated in industrial applications. Nevertheless, completely integrated operation of the TVA pilot plant remains to be demonstrated before this process is considered for full-scale application. The operating complexity and plume formation of the absorber and design of the thermal decomposer are special problems associated with this process.

Licensor

None.

ECONOMIC SUMMARY

DESIGN BASIS:	500 MW Coal-fired boiler, 3.5 percent sulfur coal
SO_2 Removal:	90-99 percent

Utility and Raw Material Requirements

Electric Power	27 MW
Steam	62 MM Btu/hr
Steam (high pressure)	77 MM Btu/hr
Reducing Agent (H_2/CO)	92 MM Btu/hr
Raw Materials (NH_3)	1,800 lb/hr

Total Utilities and Raw Materials Cost is 2.5 mils/kwh

No Capital Cost Estimate Available

ADIP/MDEA AMINE PROCESS

The Shell ADIP/MDEA gas sweetening process employs amine solvents in aqueous solutions to selectively remove H_2S from gas streams containing H_2S and CO_2. Diisopropylamine (ADIP) and methyl diethanolamine (MDEA) don't react with CO_2 as readily as other amines.

ADIP/MDEA Process

The overall flow scheme for the ADIP/MDEA process is presented in Figure A5-22. Feed gas enters the absorber at 95°F and 13.4 psia. A two stage absorber, as shown in Figure A5-23, is used to produce effluent sour gas richer in H_2S than that produced by a single stage absorber. Most of the H_2S in the feed gas is removed in the lower section of the absorber and sent to the lower stripper where it is recovered and sent to a Claus sulfur plant. The upper section of the absorber acts as a polishing section to reduce the low H_2S levels. The sour gas recovered from the upper stripper is recycled to the absorber inlet.

The chemistry for the ADIP/MDEA process is presented in Figure A5-24. MDEA is a tertiary amine with no active hydrogen and hence doesn't react chemically with CO_2. CO_2 is physically absorbed in MDEA. ADIP is a secondary amine, but reacts slowly with CO_2. Thus the absorption of CO_2 in ADIP is controlled kinetically rather than by equilibrium. MDEA absorbs less CO_2 than ADIP, but the circulation rate may be higher because of lower H_2S absorption.

The ADIP/MDEA process is capable of removing 97 percent of the H_2S. Some of the organic sulfur would probably be removed, but Shell will not guarantee it. Shell says in two of their own plants about 40 percent carbonyl sulfide is removed.

Claus Sulfur Plant

The sour off-gas from the lower stripper is sent to a conventional Claus Sulfur Plant. The feed gas stream is combined with sufficient air to burn part of the H_2S and convert it to SO_2. The reactions which occur in the Claus plant are presented in Figure A5-25. The resulting H_2S - SO_2 mixture is reacted over a Bauxite catalyst to form elemental sulfur, which is then condensed. The Claus plant recovers only 94-96 percent of the H_2S in the feed gas, and treatment of the tail gas is required.

Tail Gas Unit

The tail gas treating unit catalytically reacts a reducing gas (CO + H_2) with SO_2 at 550°F to convert the SO_2 to H_2S. The treated tail gas is cooled and recycled back with the feed to the ADIP/MDEA absorber.

Advantages

1) Capital costs are low.

2) No sludge disposal is required and a salable byproduct, elemental sulfur, is produced.

3) The DIPA and MDEA solvents selectively absorb H_2S, but little CO_2. Hence, solvent circulation rates are low, and a conventional Claus sulfur plant can be used to recover the sulfur.

4) Removal efficiencies are comparable with Stretford.

Disadvantages

1) ADIP/MDEA solvents may absorb little or no organic sulfur, thus the sulfur removal will be less than the required 95 percent.

2) The technology is unproven in this application.

3) Impurities may react nonregenerably with amines.

4) An expensive oil scrubber could be required to remove oil mist which would cause foaming of the amine.

5) Cooling of the inlet gas increases utility costs and reduced the thermal efficiency of the process.

Commercial Installations

More than 150 units have been built not including the absorption section of SCOT plants.

Licensors

Shell Development Company licenses the ADIP and MDEA processes. Shell and R. M. Parsons Company license tail gas treating processes.

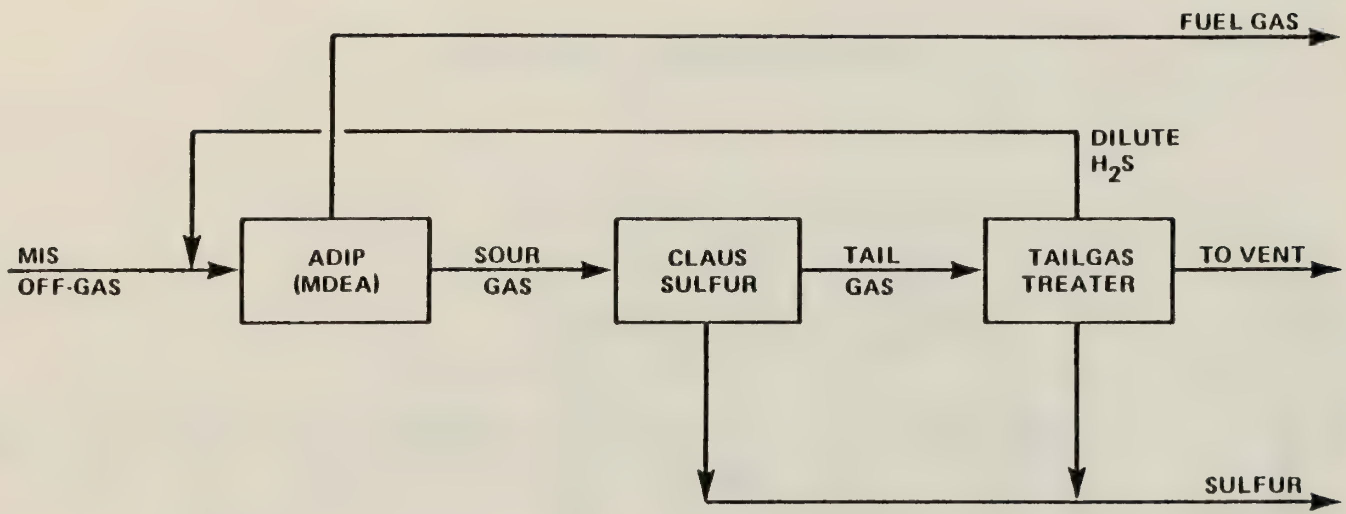


FIGURE A5-22. SULFUR REMOVAL FROM MIS OFF-GAS BY ADIP/MDEA PROCESS

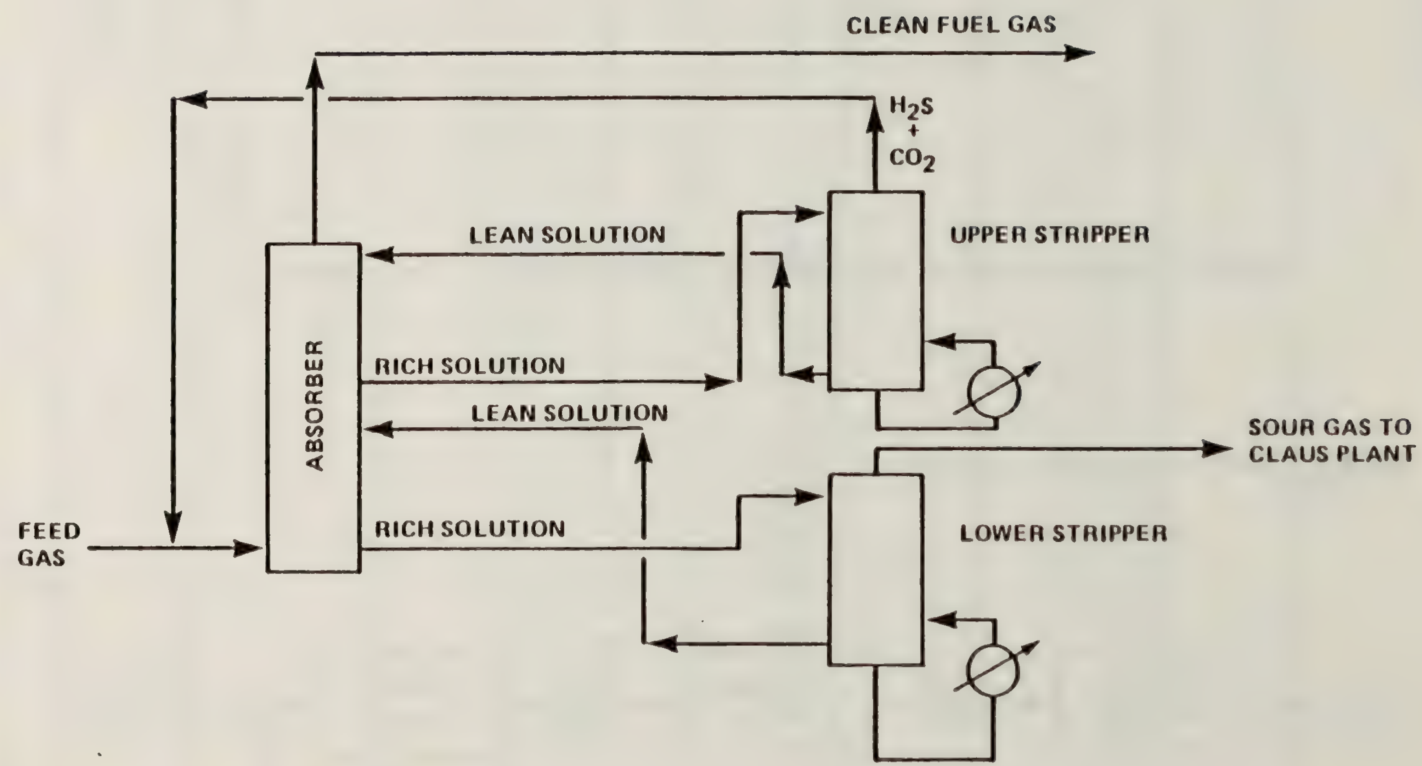


FIGURE A5-23. ADIP/MDEA PROCESS

FIGURE A5-24

ADIP/MDEA CHEMISTRY

ADIP:

ABSORPTION/REGENERATION

$R_2NH + H_2S \rightleftarrows R_2NH_3S$

$$\text{R IS-}\begin{array}{l} CH_3 \\ CH \\ CH_3 \end{array}$$

MDEA:

ABSORPTION/REGENERATION

$R^1R_2N + H_2S \rightleftarrows R^1R_2NH_2S$

R IS HO - CH_2 - CH_2 -

R^1 IS $-CH_3$

FIGURE A5-25

CLAUS AND TAIL GAS UNIT CHEMISTRY

CLAUS

$$S + O_2 \rightarrow SO_2$$

$$SO_2 + 2H_2S \rightarrow 3S + 2H_2O$$

TAIL GAS:

$$SO_2 + 3H_2 \rightarrow H_2S + 2H_2O$$

DEA PROCESS

Background - Amine Treating

Aqueous monoethanolamine (MEA) and diethanolamine (DEA) are the most widely used solutions for removal of hydrogen sulfide (H_2S) and/or carbon dioxide (CO_2) from industrial gas streams. MEA is generally used in natural gas purification while DEA is usually used in the treatment of refinery gas and liquid streams. DEA is used in the refinery applications because MEA reacts with carbonyl sulfide (COS) to form nonregenerable components, whereas DEA does not.

The process is based on the reaction of H_2S and CO_2 with aqueous ethanolamine solutions and a reversal of the reaction at the boiling point of the amine solution. The reactions of the sour gas components with DEA are:

$$2\ R_2NH_2 + H_2S \longrightarrow (R_2NH_3)_2S$$
$$(R_2NH_3)_2 + H_2S \longrightarrow 2R_2NH_3HS$$
$$2R_2NH_2 + H_2O + CO_2 \longrightarrow (R_2NH_3)_2CO_3$$
$$\text{where } R = CH_2 - CH_2 - OH$$

Description

As shown in Figure A6-25, the MIS gas is passed upward through the absorber countercurrent to the aqueous DEA solution. The H_2S and CO_2 are absorbed in the ethanolamine solution and leave the contractor in the rich DEA stream. The entering DEA solution is usually about 100°F but can be as high as 140°F.

Rich DEA is preheated in a rich solution/lean solution heat exchanger before being charged to the amine regenerator. In the regenerator, the acid gases are stripped from the rich solution by heating to 220 - 260°F along with the use of stripping steam. Stripped acid gases and stripping steam pass to a condenser where the water vapor and any amine are removed from the gas stream and returned to the stripper as reflux. The acid gas stream is routed to a Stretford unit for removal of the H_2S.

Lean DEA from the stripper is first exchanged and then cooled before returning to the absorbers.

The Stretford Process removes H_2S from the amine regenerator overhead stream. As shown in Figure 7, low H_2S contents can be attained in the treated gas at a wide range of operating pressure (0 - 1000 psig). Hydrogen sulfide removal as high as 99 percent may be obtained. Sulfur of 99 percent purity can be produced either molten or as a cake. The process can be divided

into four sections: absorption and reaction, oxidation, sulfur recovery and purification, and effluent treatment.

In the absorption section, the sour gas is contacted countercurrently in an absorber with slightly alkaline Stretford liquor. This Stretford solution contains sodium carbonate, sodium vanadate, and anthraquinone disulfonic acid (ADA). The hydrogen sulfide is dissolved and absorbed by the liquid as HS^- ions, resulting in a liquid phase concentration of HS^- equal to about 500 ppm by weight:

$$H_2S \longrightarrow HS^- + H^+$$

The solution reaches an equilibrium with respect the the CO_2 in the gas and only relatively small amounts of CO_2 are removed by the process. The treated off-gas from the absorber should contain about 20 ppmv H_2S under typical operating conditions. Each HS^- in the liquid reacts with two V^{+5} (vanadium) ions in the liquor to produce free sulfur, H_+, and 2 $V^{=4}$ ions:

$$HS^- + 2V^{+5} \longrightarrow S + 2V^{+4}$$

The Stretford liquor also contains trisodium citrate, which acts as a sequestering agent to prevent precipitation of the less soluble V^{+4}.

The liquid solution from the absorber flows to the oxidation section where compressed air is bubbled through the solution. The use of air is two-fold. First, it aids in the recovery of sulfur, since the sulfur particles attach themselves to the air bubbles and form a froth at the top of the vessel. The froth overflows continuously and is removed from the oxidizer section for recovery and purification. Second, the oxygen in the air converts the V^{+4} back to V^{+5} via oxidation in the presence of the disodium salt of ADA:

$$V^{+4} + O_2 \xrightarrow[\text{ADA}]{} V^{+5}$$

The regenerated liquor containing the oxidized form of vandadium is withdrawn and recycled to the absorber.

In the sulfur recovery section, the sulfur froth is pumped to centrifugal separators to produce a 50 weight percent sulfur cake and a clarified liquor. A portion of the liquor from the separator is used for reslurrying and the remainder is added to the Stretford solution recycle stream. The Sulfur cake is fed continuously to a sulfur reslurry tank. Reslurried sulfur is then pumped to a sulfur melter which operates with a direct steam injection. The sulfur is allowed to settle in a separator and subsequently removed from the system. A portion of the aqueous phase is recycled back to the Stretford solution makeup section and the remainder is sent to the effluent treatment section.

As gas is desulfurized by the Stretford process, sodium thiosulfate and other salts build up in the solution. To prevent salting out, a portion of the absorbing liquor must be purged from the system and replaced with fresh reagents. Treatment of this effluent stream will be necessary. The treatment can be accomplished via incineration.

Advantages DEA/Stretford

1) DEA is a regenerable process - waste disposal and reagent costs are reduced.

2) The Stretford technology has been proven.

Disadvantates - DEA

1) Does not remove organic sulfur compounds. Most of the organic sulfur compounds are removed from the MIS gas but they end up in the feed to the Stretford unit which does not remove any of the organic sulfur compounds. The net result is zero removal.

2) Non-selective acid gas removal process.

3) Sulfur recovery facilities, such as a Stretford unit, would be required for H_2S conversion. Extremely large steam requirements for DEA regeneration.

4) Technology is unproven in this application.

Disadvantages - Stretford

1) The absorber size as required is several times larger than any comercially proven absorber.

2) The blowdown liquor incineration system as proposed by the licensor has been demonstrated only on a pilot scale. Details of the system are not yet available. Other recycle systems for this stream, such as precipitaiton, are equally commercially unproven. Some Stretford operators dilute the waste or evaporate the water in a solar pond.

3) Reduction of the feed gas temperature to the absorber is a critical design consideration. The feed gas temperature must be kept at or below the Stretford liquor temperature (100 - 120°F) to prevent hydrogen sulfide from being converted to a thiosulfate. This cooling requirement of the feed gas can cause increased utility costs.

4) Heavy hydrocarbons (C_5 plus) in the gas stream tend to absorb on the sulfur, causing sulfur flotation problems in the oxidizer.

Commercial Plants

The DEA process has been used commercially in refinery gas treating for many years. General applications have been in treating sour gas streams with favorable $H_2S:CO_2$ ratios (ratios near or greater than 1).

Process Evaluation - MIS Gas Treating

The H_2S: CO_2 ratio for the MIS gas is approximately 0.006

$$\frac{(368.8 \text{ Moles/Hr } H_2S)}{(58,836 \text{ Moles/Hr } CO_2)}.$$

This low ratio means it is necessary for the DEA lean solution to remove large quantities of CO_2 from the gas stream to achieve a comparable H_2S removal. The specific impacts of having a high CO_2 MIS concentration are:

1) Extremely large solution recirculation rates - necessitates high pumping horsepower.
2) Extremely large steam requirements for the amine stripper.
3) Need to use a Stretford acid gas treater because of low H_2S concentrations in the amine stripper overhead (H_2S concentration 6 - 8% volume).

Since Stretford does not remove organic sulfur compounds from the MIS gas, it is virtually impossible to achieve an overall 95% (by weight) sulfur removal rate using this technology.

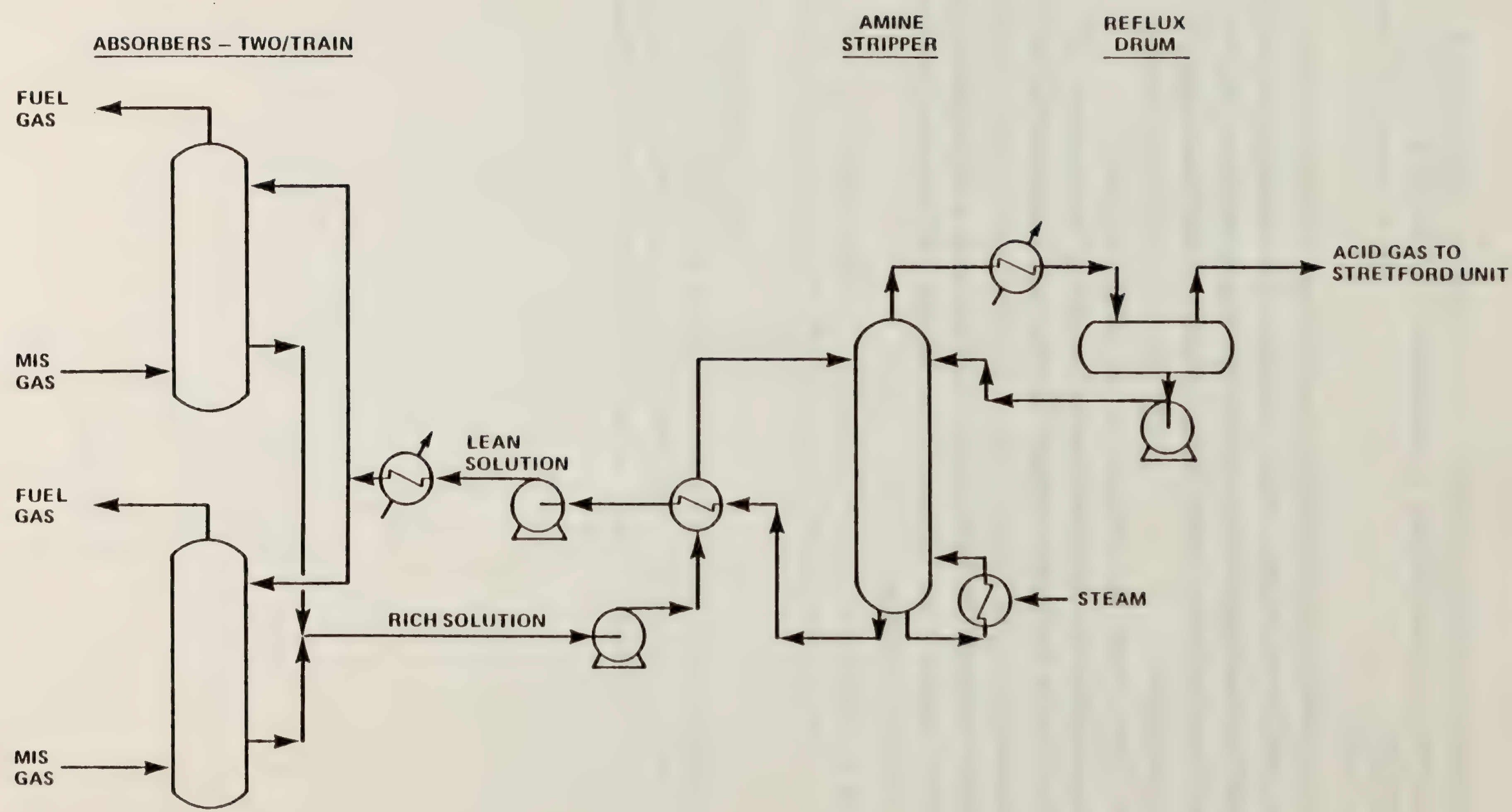


FIGURE A5-26. DEA PROCESS FLOW DIAGRAM

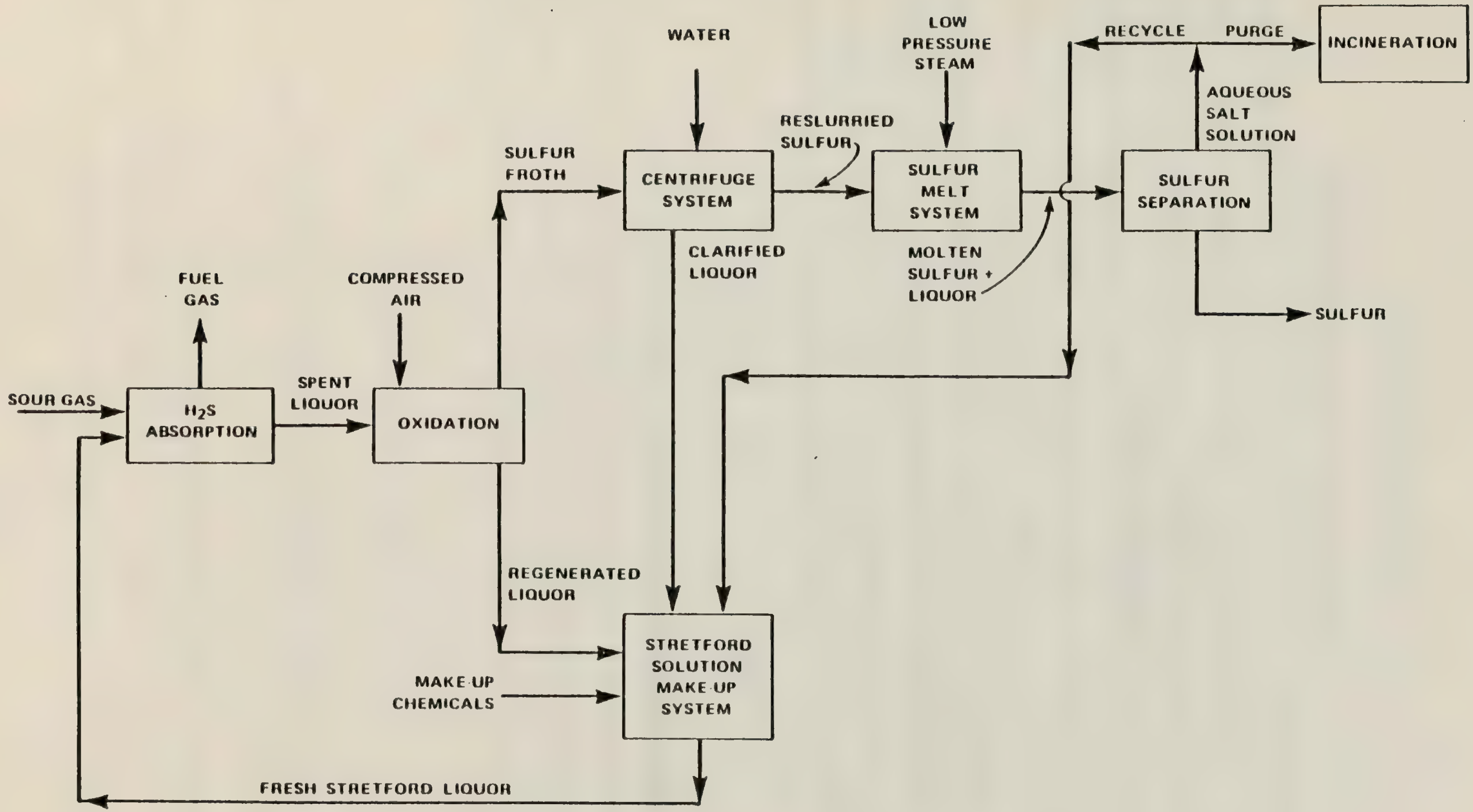


FIGURE A5-27. STRETFORD PROCESS

FIGURE A5-28

STRETFORD PROCESS

ABSORPTION:

$$H_2S \rightarrow HS^- + H^+$$

$$HS^- + 2V^5 \rightarrow S + H^+ + 2V^4$$

OXIDATION:

$$V^{+4} + O_2 \xrightarrow[ADA]{} V^{+5}$$

ADA: ANTHRAQUINONE DISULFONIC ACID

THE STRETFORD PROCESS

PROCESS DESCRIPTION OF STRETFORD PROCESS

The Stretford Process is a process for the sweetening of natural and industrial gases by the removal of hydrogen sulfide (Figure A5-29). Low H_2S contents can be attained in the treated gas at a wide range of operating pressures (0-1000 psig). Hydrogen sulfide removal as high as 99 percent may be obtained on an instantaneous basis. Sulfur of 99 percent purity can be produced either molten or as a cake. The process can be divided into the following sections: absorption and reaction, oxidation, sulfur recovery and purification, and effluent treatment.

In the absorption section, the MIS gas is contacted countercurrently in an absorber with slightly alkaline Stretford liquor. This Stretford solution contains sodium carbonate, sodium vanadate, and anthraquinone disulfonic acid (ADA). The hydrogen sulfide is dissolved and absorbed by the liquid as HS^- ions, resulting in a liquid phase concentration of HS^- equal to about 500 ppm by weight:

$$H_2S \dashrightarrow HS^- + H^+$$

The solution reaches an equilibrium with respect to the CO_2 in the gas and only relatively small amounts of CO_2 are removed by the process. The treated offgas from the absorber should contain about 200 ppmv H_2S under typical operating conditions. Each HS^- in the liquid reacts with two $V^{=5}$ (Vanadium ions) in the liquor to produce free sulfur, H^+, and 2 v^{+4} ions:

$$HS^- + 2V^{+5} \dashrightarrow S + H^+ + 2V^{+4}$$

The Stretford liquor also contains trisodium citrate, which acts as a sequestering agent to prevent precipitationof the less soluble V^{+4}.

The liquid solution from the absorber flows to the oxidation section where compressed air is bubbled through the solution. The use of air is two-fold. First, it aids in the recovery of sulfur, since the sulfur particles attach themselves to the air bubbles and form a froth at the top of

the vessel. The froth overflows continuously and is removed from the oxidizer section for recovery and purification. Second, the oxygen in the air converts the V^{+4} back to V^{+5} via oxidation in the presence of the sodium salt of ADA:

$$V^{+4} + O_2 \xrightarrow[\text{ADA}]{} V^{+5}$$

The regenerated liquor containing the oxidized form of vanadium is withdrawn and recycled to the absorber.

In the sulfur recovery section, the sulfur froth is pumped to centrifugal separators to produce a 50 weight percent sulfur cake and a clarified liquor. A portion of the liquor from the separator is used for reslurrying and the remainder is added to the Stretford solution recycle stream. The sulfur cake is fed continuously to a sulfur reslurry tank. Reslurried sulfur is then pumped to a sulfur melter which operates with a direct steam injection. The sulfur is allowed to settle in a separator and subsequently removed from the system. A portion of the aqueous phase is recycled back to the Stretford solution makeup section and the remainder is sent to the effluent treatment section.

As gas is desulfurized by the Stretford Process, sodium thiosulfate and other salts build up in the solution. To prevent salting out, a portion of the absorbing liquor must be purged from the system and replaced with fresh reagents. Treatment of this effluent stream will be necessary. The treatment may be accomplished via incineration.

a) <u>Advantages</u>

1) Instantaneous hydrogen sulfide removal is high, approximately 97-99%.

2) The technology has been proven, although on a much smaller scale than would be required by the C.B. facility.

b) <u>Disadvantages</u>

1) The absorber size as proposed by the licensor is several times larger than any commercially proven absorber.

2) The blowndown liquor incineration system as proposed by the licensor has been demonstrated only on a pilot scale. Details of the system are not yet available. Other recycle systems for this stream, such as precipitation, are equally commercially unproven. Some Stretford operators dilute the waste or evaporate the water in a solar pond. The new RCRA rules yet to be published, will likely dictate the method of disposal.

3) Reduction of the feed gas temperature to the absorber is a critical design consideration. The feed gas temperature must be kept at or below the Stretford liquor temperature (100 - 120°F) to prevent hydrogen sulfide from getting tied up as thiosulfate. This cooling requirement of the feed gas causes increased utility costs.

4) Heavy hydrocarbons (C_5 plus) in the gas stream tend to absorb on the sulfur, causing sulfur flotation problems in the oxidizer.

5) The process does not, to any significant degree, remove orgainic sulfur compounds (e.g. CS_2, COS, CH_3SH) from the gas stream. Therefore, the overall sulfur removal is a funciton of the quantities of such compounds in the feed gas.

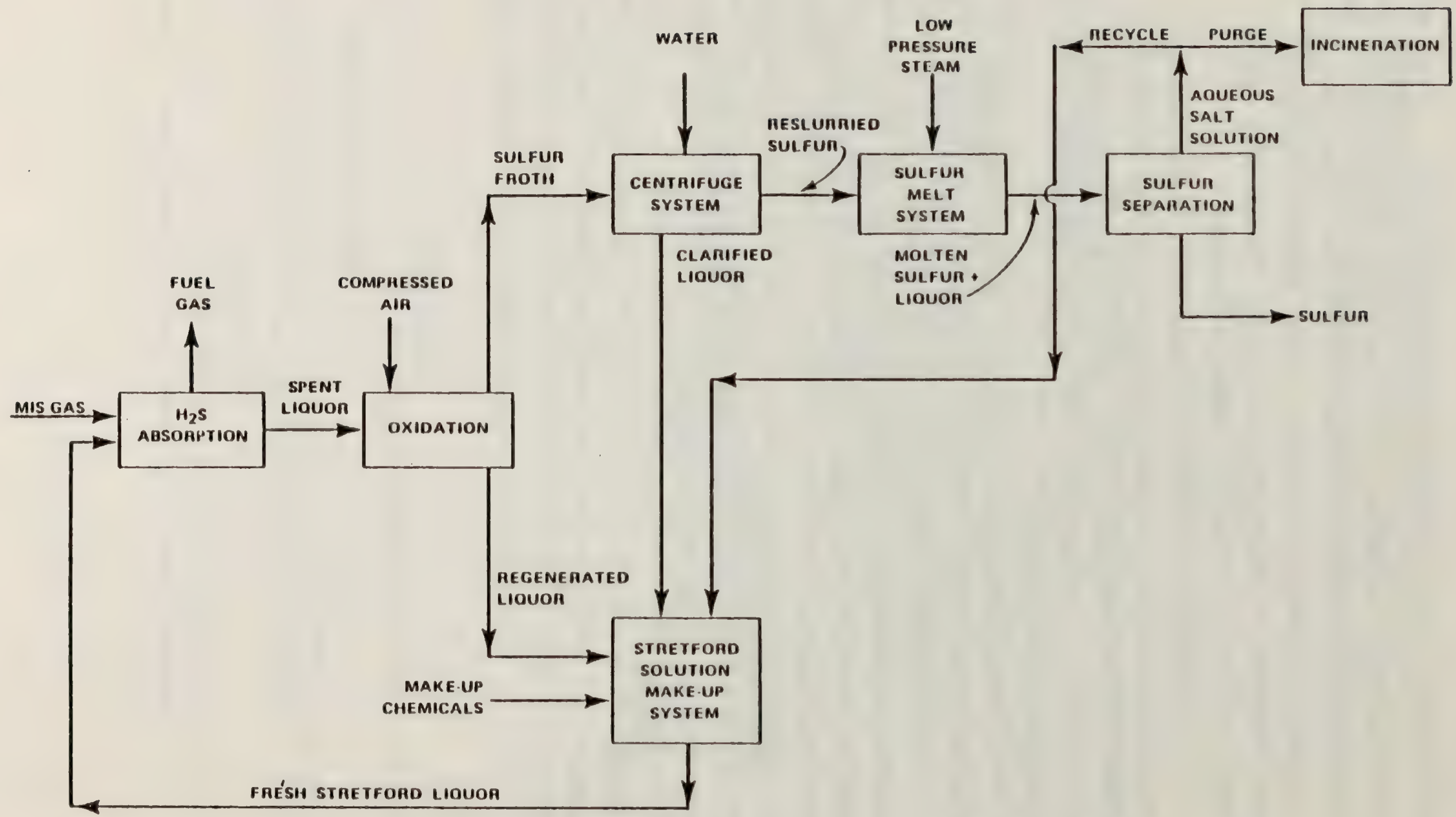
c) <u>Commercial Installations</u>

Over 125 Stretford units are currently constructed or in construction with capacitites ranging from 0.1 to 500 MM SCFD per unit.

d) <u>Licensor</u>

Peabody Process Systems

R. M. Parsons Company



A5-29. STRETFORD PROCESS

ORGANIC SULFUR CONVERSION/STRETFORD PROCESS

The Stretford process is limited in its capability to remove orgainic sulfur compounds from the flue gas. As a result the result the removal efficiency for sulfur compounds (including hydrogen sulfide) is about 95.5 percent. It is technically feasible to remove all the sulfur compounds to a very low level by the use of a Stretford unit followed by a Beavon Sulfur Removal Plant (BSRP) which combines a cobalt-molybdenum catalyst bed with another Stretford unit. (Figure A5-30).

The first Stretford unit will remove 99.5 percent of the hydrogen sulfide, leaving most of the organic sulfur species, carbonyl sulfide, carbon disulfide and mercaptans. This initial step is necessary to permit the catalytic hydrolysis reaction to take place in the cobalt-molybdenum catalyst bed, because the presence of hydrogen sulfide inhibits the reaction. With the hydrogen sulfide removed, the catalytic reaction can proceed to convert the organic sulfides to hydrogen sulfide. Then the following Stretford train will remove the balance of the hydrogen sulfide.

For the catalytic reaction to proceed, the flue gas will have to be heated to 650°F from 95°F requiring a heater and heat recovery equipment adequate to transfer about on billion BTU/HR. The reactions over the catalyst may be summarized as follows:

$$COS + H_2 \text{--->} H_2S + CO$$
$$CS_2 + 4H_2 \text{--->} 2H_2S + CH4$$
$$R\text{-}SH + H_2 \text{--->} H_2S + RH$$

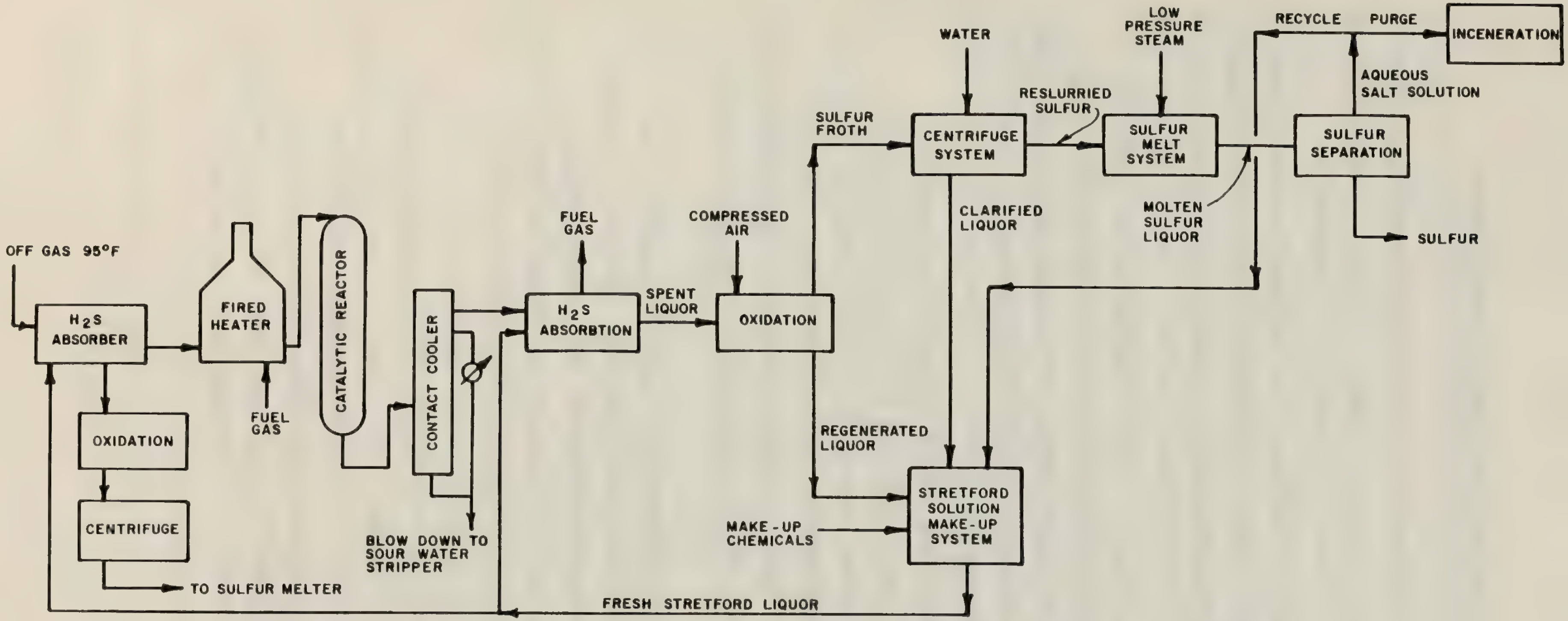
a) Advantages

1) Organic sulfur compounds can be removed from the off-gas allowing over 99 percent sulfur recovery on an instantaneous basis.
2) The Stretford process is commercially well established.
3) The use of cobalt-molybdenum catalyst for the hydrolysis of sulfur compounds has been demonstrated in many applications.

b) Disadvantages

1) The amount of catalyst required is 75,000 to 100,000 cubic feet for Cathedral Bluffs. At $125/cubic feet, the cost for catalyst will be about $9,400,00 to $12,500,000.

2) The required gas temperature for the reaction to proceed demands a large heater and a large cooler to cool the gas to a satisfactory temperature for the Stretford unit.
3) The catalyst beds will have about 1.5 pounds per square inch pressure drop, thus adding 19,800 BHP to the overall compressor energy consumption.
4) The process will cost as much as two Stretford processes; plus the cost of heaters, fuel and waste heat boilers to handle the heat input required; plus the cobalt-molybdenum catalyst and its containing vessels.
5) At the present time there is no known commercial application of the Stretford-Catalyst-Stretford train.



A5-30. STRETFORD PLANT WITH BEVIN STRETFORD

PROCESS DESCRIPTION OF RESEARCH-COTTRELL PROCESS

The Research-Cottrell Process for flue gas desulfurization is a Double-Loop Limestone slurry process which can remove 95 percent of the SO_2 in the flue gas (Figure A5-31).

The system is designed with two separate sections to provide two process loops operating at different chemical conditions which improve reagent usage compared to the single loop limestone process, while still maintaining high removal of SO_2.

The absorber loop (see Figure A5-31) is maintained at a pH of about 6 by varying the flow and the solids composition of the limestone slurry fed to the top of the packing of the upper section of the absorber tower. The high pH favors removal of SO_2. The slurry from the absorber tower is collected and returned to the absorber tank.

The quencher loop (see Figure A5-31) is maintained at a pH of about 4.5 by varying the flow of makeup limestone slurry from the absorber tank. The inlet flue gas to the system is contacted with a spray of limestone slurry pumped from the bottom of the absorber tank. The spent slurry (15% solids) from the quencher/absorber tank is removed via level control and sent to the dewatering section. The high solids content and low pH favor reagent usage.

The flue gas flows upward through the quencher/absorber tower, around the collection pan in the absorber tower, and then through the wetted film contactor and demisters in the upper section of the absorber tower.

The oxygen in the flue gas will partially oxidize the calcium sulfite to calcium sulfate. Oxidation is favored by the lower pH in the quencher/absorber tower. Air can be injected in the bottom of the quencher/absorber tower to increase the formation of calcium sulfate from about 50% conversion to complete oxidation.

Oxidation changes the crystal structure from flat, plate-like $CaSO_3$ to dense, monoclinic $CaSO_4$ particles. Oxidation improves settling time, filterability, and landfill properties. Calcium sulfite is thixotropic, which can cause disposal problems because of instability.

Water is removed from the spent slurry by cyclone and vacuum filters to provide a filter cake with about 20% free water. The filter cake is mixed with spent shale from the surface retorting units to form a suitable landfill material.

Limestone is delivered to the site by truck and unloaded by conveyors to a storage shed. The limestone is then conveyed to weigh bins which charge ball mills that pulverize the limestone to less than 200 mesh. Water is also fed to the ball mills to provide a pumpable slurry which is stored at 30-40% solids in the reagent feed tank. The slurry is pumped through a loop to the absorber tank.

The chemistry of the Research-Cottrell Process can be separated into three steps: absorption, slurry reaction and precipitation, and oxidation. In the absorption step, the gaseous sulfur species react with the absorbing liquid according to the following unbalanced equations:

$$SO_2 \underset{H_2O}{\rightleftharpoons} H_2SO_3 \underset{H_2O}{\rightleftharpoons} 3H^+ + HSO_3^- + SO_3^{-2}$$

$$SO_3 \rightleftharpoons H_2SO_4\ (aq)$$

The limestone ($CaCO_3$) then reacts with SO_3^{-2} according to the following unbalanced equations:

$$CaCO_3 \underset{H_2O}{\rightleftharpoons} Ca^{+2} + HCO_3^- + CO_3^{-2}$$

$$Ca^{+2} + SO_3^{-2} \xrightarrow{H_2O} CaSO_3 \cdot 1/2H\ O_2(s)$$

The calcium sulfite hemihydrate can then be oxidized to calcium sulfate dihydrate (gypsum):

$$CaSO_3 \cdot 1/2H_2O + 1/2O_2 + 3/2H_2O \longrightarrow CaSO_4 \cdot 2H_2O\ (s)$$

The two loop operation results in full utilization of the limestone reagent and SO_2 removal rates of 95 percent.

a) Advantages

1) The process has been proven on large scale power plants in the U.S.A. The plants are several hundred megawatt units and have been onstream for several years.

2) The process consumes limestone as a raw material which is less expensive than lime or soda ash.

3) SO_2 removal of 95% has been commercially demonstrated.

b) Disadvantages

1) Relatively high capital cost is associated with the process.

2) Slurry circulation of limestone is used; more maintenance can be expected as a result of plugging, solids deposition, or abrasion.

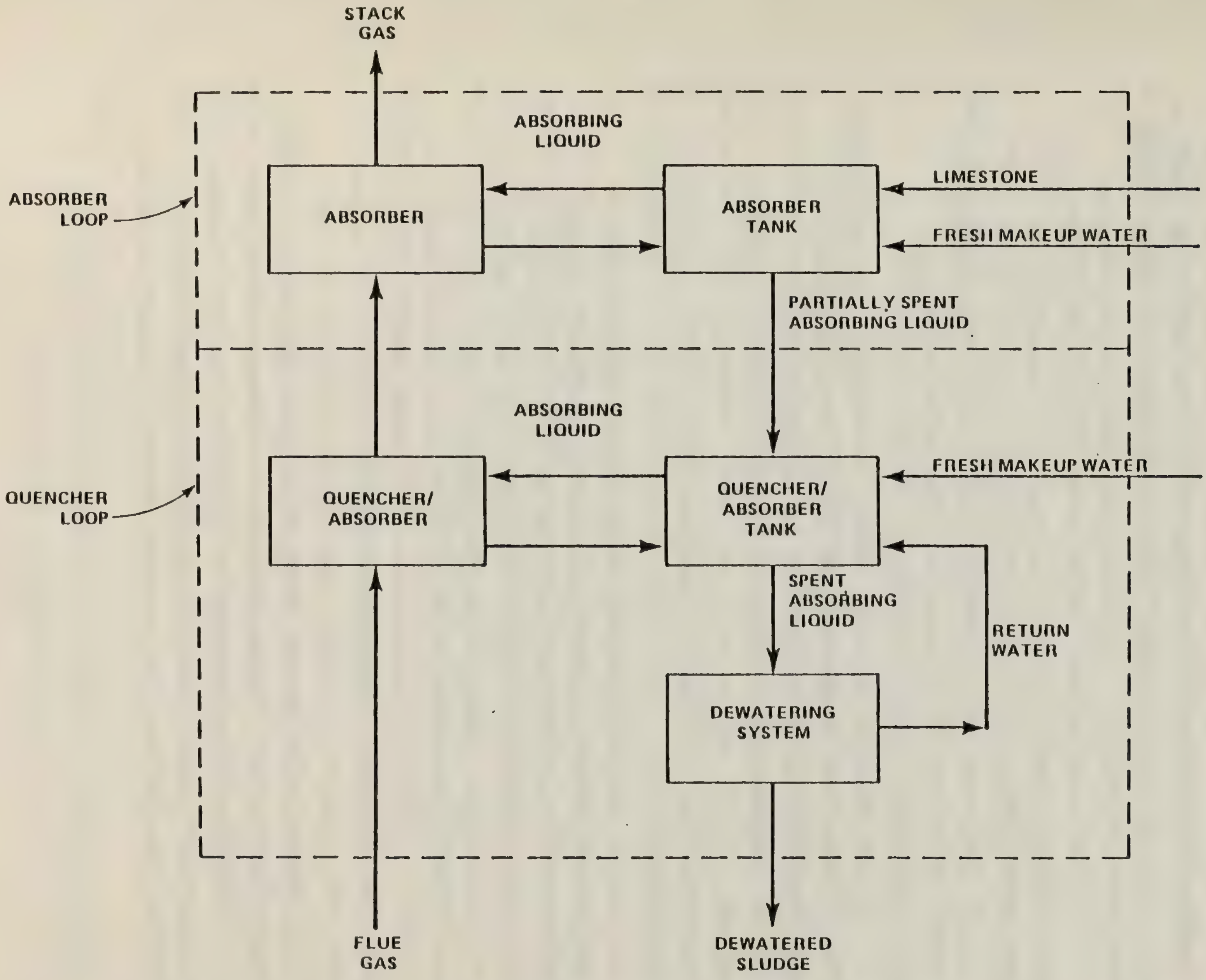
3) Large quantities, of limestone must be transported to the jobsite.

c) Commercial Installations

A Research-Cottrell unit is in operation at the Cholla station for Arizona Public Service Co. This installation has operated for approximately 3 1/2 years. Another Research-Cottrell unit has been in operation since 1977 at Texas Utilities' Martin Lake Steam Electric Station.

d) Licensor

Research-Cottrell



A5-31. RESEARCH - COTTRELL PROCESS

PROCESS DESCRIPTION OF DAVY SAARBERG-HOLTER (S-H) PROCESS

The Davy Saarberg-Holter (S-H) Process for flue gas desulfurization is a wet scrubbing process based on lime (Figure A5-32). The process can remove 95 percent of the SO_2 in the flue gas. The Davy S-H Process has several unique features which distinguish it from conventional lime/limestone processes:

1) The use of a clear alkaline scrubbing fluid (not a slurry) for absorption of SO_2. There will be no plugging, solids deposition, or abrasion in the scrubber.

2) The system uses a carboxylic acid to buffer the scrubbing fluid and control the pH drop during absorption. This allows better SO_2 absorption and higher chemical efficiency.

3) The formation of a water soluble intermediate, calcium bisulfite ($Ca(HSO_3)_2$) rather than insoluble calcium sulfite hemihydrate ($CaSO_3 \cdot 1/2H_2O$). There is no solids formation in the absorption system.

4) The production of gypsum by forced oxidation in a separate process step.

The process can be divided into three main parts: absorption, oxidation and separation.

The flue gas entering the absorption section must be below 400°F.

The SO_2-rich stream is contacted co-currently in ROTOPART absorber separators with a clear alkaline scrubbing solution of calcium hydroxide, calcium formate, and calcium chloride. These materials absorb the SO_2 and form the water-soluble intermediate calcium bisulfite ($Ca(HSO_3)_2$). This compound is the only water-soluble calcium sulfur oxide compound known, and its formation in substantial concentrations is dependent upon the pH, pH buffering, and temperature. The ROTOPART absorber consists of one or more absorbing ducts sized on a residence time/velocity criteria basis. The velocity of the gas in the absorber should be low enough to allow time for the calcium bisulfite to form. However, the residence time must also be short enough to prevent significant oxidation of the calcium bisulfite to gypsum, $CaOS_4 \cdot 2H_2O$, because oxygen in the flue gas from excess combustion air is available for the oxidation. This oxidation reaction is undesirable at this point.

Absorption of SO_2 is achieved by reaction with the active components of the washing fluid at relatively high pH (8-11):

$$2OH^- + 2SO_2 \longrightarrow 2HSO_3^-.$$

As OH^- ions from the solution are consumed in the absorption reaction, an abundance of H^+ ions are made available through

$$H_2O \longrightarrow H^+ + OH^-.$$

The pH of the solution thus drops rapidly to 4.5-5.0. The H^+ ions then react with formate ions ($HCOO^-$) according to

$$HCOO^- + H^+ \longrightarrow HCOOH.$$

The formic acid which is formed serves to buffer the solution at 4.5-5.0, the pH range necessary for formation of calcium bisulfite. Formation of molecular HCOOH is enhanced as a result of excess H^+. By preventing a rapid drop in pH, a high SO_2 removal takes place in the pH range 4.0-5.8. After the formate ion is largely consumed, the buffering effect is weakened and the pH of the absorbing fluid drops to approximately 4.0. This particular acidity level is optimum for the subsequent forced oxidation step.

The desulfurized flue gas from all the absorbing ducts is separated from the washing fluid in the ROTOPART separator. The clean gas is separated from the liquid by centrifugal force and discharged to the atmosphere. The scrubbing solution is sent to an oxidation system.

In the oxidizers, air is used to convert calcium bisulfite to calcium sulfate dihydrate (gypsum):

$$Ca^{+2} + 2HSO_3^- + 2OH^- + O_2 \longrightarrow CaSO_4 \cdot 2H_2O + SO_4^{-2}.$$

The crystalline calcium sulfate which is produced by oxidation is kept in suspension by the mixing action of the compressed air. The oxidized scrubbing fluid overflows into a mixing channel. In this channel, slurried lime ($Ca(OH)_2$) is added to the scrubbing fluid to replenish calcium ions consumed by the formation of gypsum in the oxidizer and to adjust the pH value to that required for SO_2 absorption:

$$Ca(OH)_2 \longrightarrow Ca^{+2} + 2OH^-$$

$$2HCOOH + 2OH^- \longrightarrow 2HCOO^- + 2H_2O.$$

The sulfuric acid formed in the oxidizer is converted into additional gypsum:

$$2H^{+} + SO_4^{-2} + Ca^{+2} + 2OH^{-} \longrightarrow CaSO_4 \cdot 2H_2O.$$

A small amount of formic acid is added to make up for losses of the calcium salt in the wet filter cake produced downstream. If the flue gas does not contain chlorides, a small amount of hydrochloric acid is also added to increase the solubility of calcium hydroxide. Turbulence in the mixing channel provides thorough distribution of the added chemicals.

The slurry from the mixing channel is sent to the separation section. A thickener is used to separate the gypsum crystals formed in the oxidizer and mixing channel from the washing fluid. The crystals (10-30% slurry) are pumped from the bottom of the thickener to a vacuum filter. The vacuum filter produces a gypsum cake containing approximately 80% solids (20% free H_2O). The filtrate is recirculated to the thickener. The clear overflow from the top of the thickener is recycled to the ROTOPART absorbers as a scrubbing fluid.

Since the gypsum formed by the process is precipitated, calcium ions removed from the system must be continually replaced by the addition of CaO. Additionally, the water that leaves the system with the gypsum contains small amounts of calcium hydroxide required for absorption. These small quantities are periodically added to the system.

a) Advantages

1) The capital and utilities costs are low.

2) Evaporation of water and incorporation of water into the gypsum matrix is a natural part of the process. This would utilize briny water separated from the process stream.

3) The filter cake is fully oxidized from $CaSO_3$ to $CaSO_4$ and is thus stabilized. The gypsum sludge behaves as a conventional solid and is not thixotropic.

4) All equipment is made of carbon steel except for one small portion which is coated with epoxy.

5) Lesser daily tonnages of reagent (lime rather than limestone) must be transported to the jobsite.

b) Disadvantages

1) Purchased lime as the raw material is considerably more expensive than limestone. Alternatively, purchased limestone could be used, but energy-intensive calcining facilities would have to be installed and operated at the jobsite.

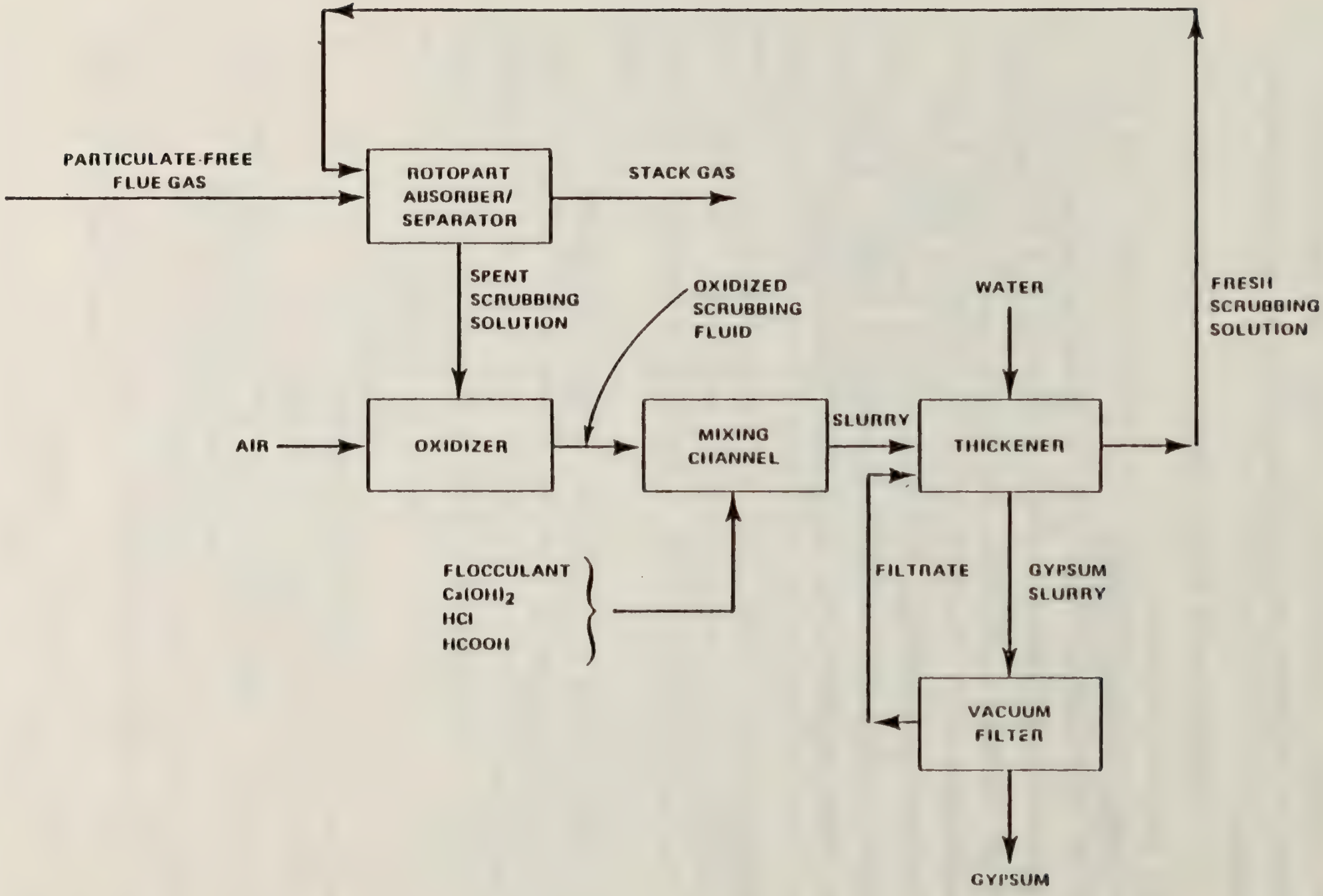
2) The application of this process is not as extensive worldwide as some of the other processes.

c) Commercial Installations

The first demonstration plant on Saarbergwerke Weiher II power plant near Dusseldorf, West Germany, utilizing the Davy S-H Process was constructed in 1974 and has been in operation over 20,000 hours, treating 80,300 SCFM with 96% reliability. A larger S-H unit for a 700 MW coal-fired boiler (Saarberwerke Weiher III) has been in operation since March, 1979. This unit treats 25% of the flue gas, which is equivalent to 175 MW. An even larger S-H unit for an 800 MW plant is currently under construction in Berlin.

d) Licensor

DM International, Inc.



A5-32. DAVY SAARBERG - HOLTER SCRUBBING PROCESS

PROCESS DESCRIPTION OF FMC DOUBLE ALKALI PROCESS

The Double Alkali Process is a dual chemistry process (Figure A5-33). Sulfur dioxide (SO_2) is absorbed from flue gas in an absorber designed to allow high sulfur dioxide collection efficiencies (up to 95%). This high collection efficiency is achieved with a pressure drop (less than 5 in. H_2O) which is lower than that of the other FGD systems considered. The absorber contains a series of discs and donuts over which the scrubbing liquor flows countercurrent to the gas flow. The scrubbing solution is a clear, concentrated, highly reactive solution containing sodium sulfite (Na_2SO_3), sodium bisulfite ($NaHSO_3$), and sodium sulfate (Na_2SO_4). As SO_2 is absorbed, the sodium sulfite is converted to sodium bisulfite according to the following reaction:

$$Na_2SO_3 + SO_2 + H_2O \dashrightarrow 2NaHSO_3.$$

A small percentage of the sodium sulfite also reacts with oxygen from the flue gas to form sodium sulfate, depleting the sodium in the system:

$$2Na_2SO_3 + O_2 \dashrightarrow 2Na_2SO_4.$$

A bleed stream is taken from the scrubbing solution recirculating system in the SO_2 absorption loop at the same rate (SO_2 basis) that SO_2 is being removed. The bleed stream is sent to the regeneration loop where the sodium bisulfite is reacted with slaked lime ($Ca(OH)_2$) in a low residence time continuously stirred tank:

$$4NaHSO_3 + 2Ca(OH)_2 \dashrightarrow 2Na_2SO_3 + 2CaSO_3 \cdot 1/2H_2O + 3H_2O$$

The reaction of lime and sodium bisulfite regenerates sodium sulfite which is returned to the scrubbing solution recirculation tank for reuse.

FIGURE I - IV, II

DOUBLE ALKALI PROCESS

SO_2 ABSORPTION:

$Na_2SO_3 + SO_2 + H_2O \text{ ---> } 2NaHSO_3$
(SODIUM SULFITE) (SODIUM BISULFITE)

$NaOH + SO_2 \text{ ---> } NaHSO_3$

ACTIVE SODIUM MAKEUP

$NaHCO_3 + SO_2 \text{ ---> } NaHSO_3 + CO_2$
(SODIUM BICARBONATE)

$Na_2CO_3 + 2SO_2 + H_2O \text{ ---> } 2NaHSO_3 + CO_2$
(SODA ASH)

SULFATE FORMATION IN SCRUBBING SOLUTION

$Na_2SO_3 + 1/2O_2 \text{ ---> } Na_2SO_4$
(SODIUM SULFATE)

REGENERATION OF SCRUBBING LIQUID

$4NaHSO_3 + 2Ca(OH)_2 \text{ ---> } 2Na_2SO_3 + 2CaSO_3 \cdot 1/2H_2O) + 3H_2O$
(SLAKED LIME) (CALCIUM SULFITE)

Sodium hydroxide (NaOH), sodium bicarbonate ($NaHCO_3$), or soda ash (Na_2CO_3) is added to the scrubbing solution as makeup for loss of active sodium from the system. These compounds react with SO_2 to form sodium bisulfite:

$$NaOH + SO_2 \text{--->} NaHSO_3$$

$$NaHCO_3 + SO_2 \text{--->} NaHSO_3 + CO_2$$

$$Na_2CO_3 + 2SO_2 + H_2O \text{--->} 2NaHSO_3 + CO_2.$$

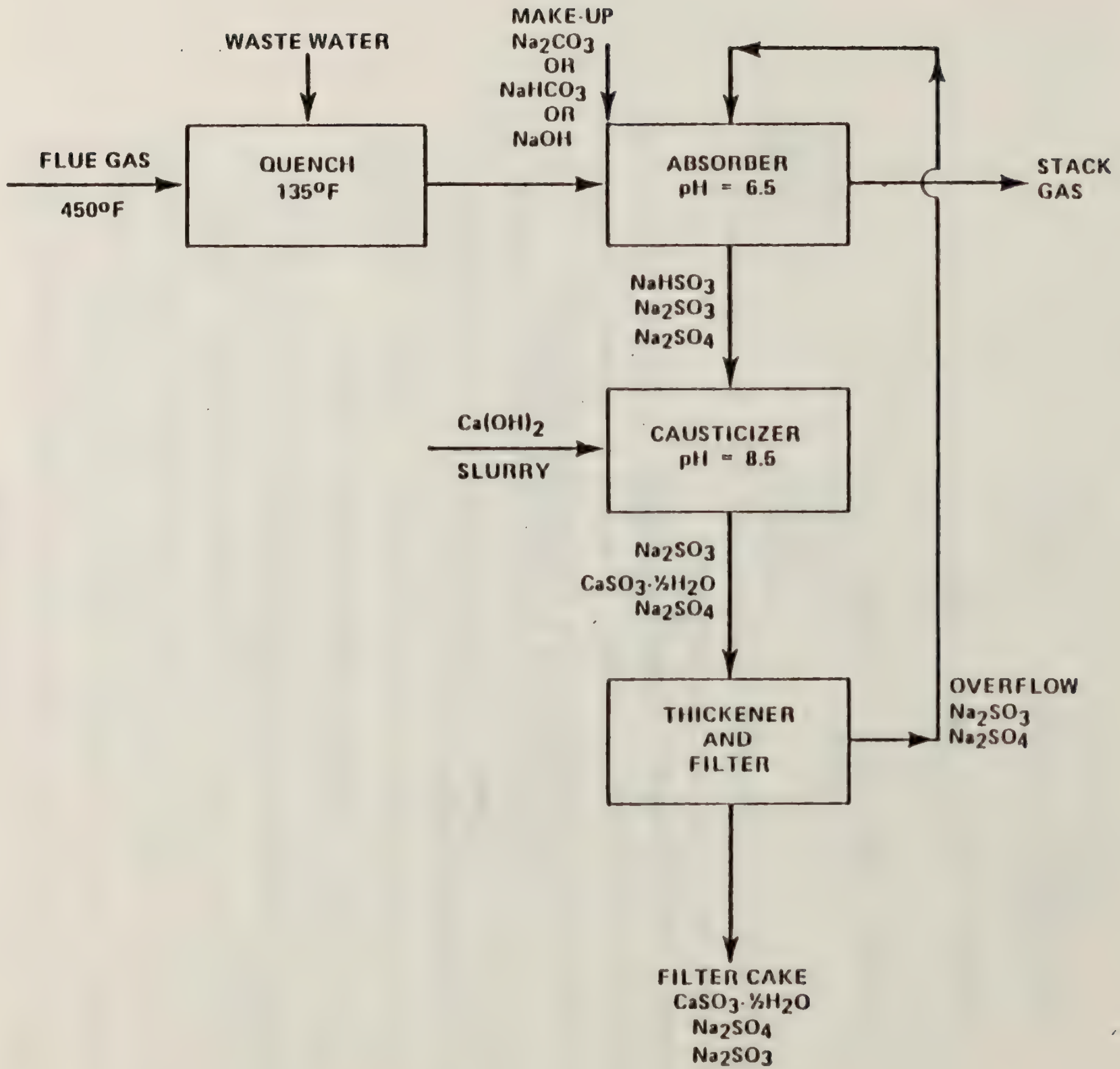
The calcium sulfite ($CaSO_3$) precipitate is fed from the lime reactor to the thickener where the solids are concentrated.

The slurry from the thickener is pumped to vacuum filters where a filter cake consisting of 55-70% solids is formed and washed to minimize the amount of entrained soluble sodium compounds. The filter cake has strength comparable to that of a soft to medium clay and could be used for landfill only where strength and settlement considerations are of little importance. Alternatively, the calcium sulfite could be oxidized to calcium sulfate (gypsum) to produce a more stable product for landfill. However, additional equipment would be required for this oxidation step.

The scrubbing solution is controlled at a pH of 6.5 where the sulfite/bisulfite solution is highly buffered and can readily adapt to rapid changes in inlet SO_2 concentrations while maintaining removal efficiency. Above a pH of 7, carbon dioxide absorption becomes significant and can lead to calcium carbonate scaling. A scrubbing solution pH of 6 is likewise avoided because the vapor pressure of the sulfur dioxide increases dramatically with decreasing pH and can lead to equilibrium limited scrubbing conditions where low outlet sulfur dioxide concentrations are required.

The regeneration of sodium bisulfite with lime is controlled at a pH of 8.5 which is effectively the titrimetric end point for sodium bisulfite.

Operating at this pH assures good responsiveness of the control system, therefore reducing the need for adding excess lime. In addition to poor chemical utilization, excessive lime results in poor filter cake quality and



A5-33. DOUBLE ALKALI PROCESS

substantially higher operating costs. Maintaining the high dissolved sulfite concentration in the scrubbing liquid results in a dissolved calcium concentration considerably below the saturation level. This condition eliminates the possibility of calcium sulfate scale formation.

A major difficulty with the double alkali process is the sodium sulfate (Na_2SO_4) produced in the scrubber by the rapid reaction of sodium sulfite with oxygen in the flue gas. The Na_2SO_4 cannot be readily regenerated into an active sodium form by reaction with lime. Compositions of the flue gas and of the solution have significant effects on the rate of sulfate formation. High oxygen concentration in the flue gas leads to excessive sulfate formation and results in a significant increase in operating costs for soda ash makeup. The rate of net soluble sulfate formation is reduced by maintaining a high ionic strength scrubbing solution, principally in the form of increased sulfate concentration. Soluble sodium side-products leave the process entrained in the filter cake. Total sodium consumption is approximately 2-5% by weight of the SO_2 collected for most applications, but can be over 10%, depending on operating conditions.

a) Advantages

1) The capital costs are low.

2) It has been proven in the U.S.A. on several power plants.

3) A clear solution contacts the gas stream, avoiding solids plugging, deposition and abrasion problems.

b) Disadvantages

1) Na_2SO_3 reacts with oxygen in the flue gas to form inactive, soluble Na_2SO_4. The inactive Na_2SO_4 must be purged from the system and replaced with soda ash as makeup.

2) The necessary purge of soluble Na_2SO_4 from the system could complicate the plant disposal problems.

3) The filter cake produced in the process ($CaSO_3 \cdot 1/2H_2O$) is thixotropic. Stabilization by oxidation would be required to improve the strength and settlement characteristics of the material for it to be used alone as a landfill material.

4) The ability for the process to utilize brines is questionable.

c) Commercial Plants

There are nine major flue gas desulfurization installations in operation using the Double Alkali Process in utility and industrial applications. Three of these are owned by Caterpillar Tractor Company. The others are owned by FMC, Firestone, Transco Textiles, Canton Textile and Alyeska. Three more plants are in the design or construction phase. The largest plant to date is a 250 MW coal-fired utility boiler using coal with a sulfur content of up to 4.5% by weight. The operating plants have an average of 95% on-stream time. In addition, a unit is being constructed for testing at the C-a Tract for Rio Blanco Oil Shale Company.

d) Licensor

FMC Corporation.

6.0

APPENDIX 6.0

Tracer Study at the Federal Prototype Oil Shale Lease Tract C-b in Rio Blanco, Colorado

AV R 8172

Report on

TRACER STUDY AT THE FEDERAL PROTOTYPE OIL SHALE LEASE TRACT C-b IN RIO BLANCO, COLORADO

Prepared for

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October 1978

ACKNOWLEDGEMENTS

This experiment could not have been successfully conducted without the dedication and perseverence of the other members of the team, besides the authors. They are:

Jerry Thelen – the field manager

Al Morris – weather forecaster and consultant

Steve Hernandez, Bob Baxter and Floyd Mesler – instrument technicians

Gee Lowe, Sara Head and Jamie Yuan – field technicians

Ample guidance and cooperation was also given to us by Dr. George Fosdick of Occidental Oil Shale, Inc. throughout the experiment.

This report was typed and graphics for the report were prepared by the Information Management Department of AV under the direction of Diane Barker.

TABLE OF CONTENTS

1. INTRODUCTION

The C-b Oil Shale Venture plans to construct and operate an ancillary facility consisting of two or more commercial-sized retorts on Federal Oil Shale Lease Tract C-b, which is located about 20 miles west of Rio Blanco, in Rio Blanco County, Colorado (Figure 1-1). This ancillary facility will permit the processing of a thick section of high grade oil shale, establish the environmental monitoring procedures, obtain operating experience for processing a cluster of retorts, and provide a site for the training of mine and processing personnel.

To secure an air quality permit for this operation from the Colorado Department of Health, an air quality impact assessment of the ancillary facility is required. This impact assessment has to demonstrate compliance with Prevention of Significant Deterioration (PSD) Regulations and National and State Ambient Air Quality Standards through detailed air pollution modeling. Since Tract C-b is located in complex terrain, readily available EPA models which were developed for flat land do not provide realistic answers. Thus, a complex terrain model, AVMSTM, developed by AeroVironment (Chan, et al, 1977) is being adjusted to the conditions on Tract C-b and will be used for assessing the impacts of the ancillary facility.

In order to ensure the applicability of the adjusted model, a model validation experiment was performed in September 1978 on Tract C-b. This experiment was originally planned to be carried out in late 1977 but inclement weather had prevented any successful attempts until the fall of 1978. In the interim, however, trial runs were made to test the equipment and procedure. Data collected during those trial runs were not meaningful because of equipment problems or because of unfavorable weather conditions. They have been presented elsewhere (Chan, 1978) and thus will not be repeated here.

This report gives a description of the experiment performed in September of 1978, presents the data collected, and discusses the results of the experiment.

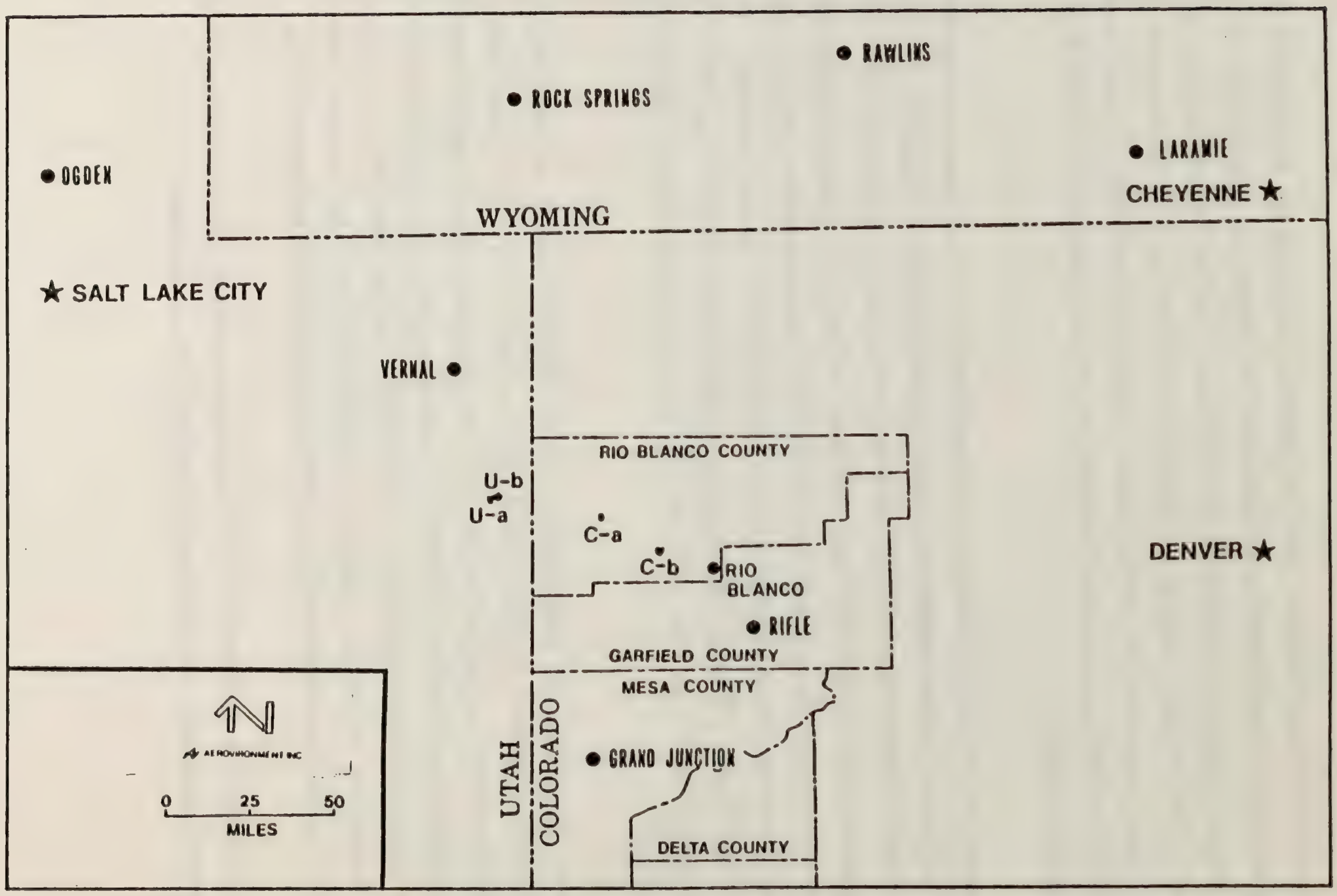

FIGURE 1-1. Regional map showing location of Tract C-b.

2. THE EXPERIMENT

The objective of the experiment was to simulate the transport and dispersion of emissions from an elevated source in the vicinity of the proposed ancillary facility under meteorological conditions conducive to high ground level concentrations.

For inert pollutants, the meteorological conditions of interest consist of low wind speed, persistent wind direction, and a neutral or stable atmospheric structure. Another situation of concern occurs when solar heating in the morning destroys a noctural radiation inversion, bringing high concentrations to the surface along the plume centerline. This process is known as fumigation.

Of course, an ideal experiment would be to determine the transport and dispersion of pollutants under all imaginable meteorological conditions. But since resources are limited, the days on which such an experiment would be performed should consist of a well-established noctural radiation inversion, followed by the destruction of that inversion in the morning, which is preceded or followed by a neutral atmospheric condition.

Since November 1977, a watchful eye was kept on the weather over the tracts by Mr. Alvin Morris of Ambient Analysis, Inc., through the winter and spring of 1978. Unfortunately, the conditions we were looking for never lasted long enough to allow the experiment to be conducted. No action was taken during the summer since atmospheric turbulence is usually higher as a result of stronger and longer solar heating of the earth's surface; which means quicker dispersion of pollutants and thus would not provide the ideal situation conducive to high concentrations. The early fall of 1978 had a number of days with the desired conditions, however, and the experiment was finally conducted on the 14th and 15th of September 1978.

2.1 Tracer Gas Releases

The simulation of emissions from an elevated source was accomplished by releasing sulfur hexafluoride (SF_6) at an elevation that approximated the final height of the plume from the proposed ancillary facility (about 100 m above ground level). The SF_6 gas was supplied by Air Products & Chemicals, Inc., with specifications of 99.65 vol % purity. SF_6

was chosen as the tracer gas because it can be detected down to 10^{-12} parts of SF_6 per part of air (i.e., 1 ppt) and has a natural background of 0.0 to 0.1 ppt. It also possesses the following properties that makes it an ideal tracer gas:

- Nontoxic, nonallergenic, nonradioactive, colorless and odorless.

- Gaseous at ambient temperatures.

- Chemically inert and thermally stable for atmospheric applications.

- Capable of rapid and controlled atmospheric release from a point or area source.

- Amenable to conventional and standardized collection techniques.

- Commercially available at a reasonable price.

A Raven TRFD-1500 tethered balloon (Figure 2-1) was used to carry a one-inch plastic tubing to an altitude of about 100 m (330 feet) above the ground (Figure 2-2). The other end of the plastic tubing was attached to the SF_6 cylinder (Figure 2-3). SF_6 was then released at about 425 scmh. The pressure from the cylinder was sufficient to force the SF_6 through the length of the tubing and allowed the gas to be released at the desired elevation.

A steady release rate was achieved by using a two-stage regulator and a rotometer which had been calibrated by use of a dry test meter. An Accu-Weight Model 300T scale was employed to measure the cylinder weights at 15-minute intervals. This arrangement is depicted in Figure 2-3. The tracer release rate was calculated from the difference in weight and was also cross-checked against the rotometer reading to assure that the release rate was constant.

The best location of release would have been the site of the ancillary facility. Ongoing construction at that site, however, prevented the release from taking place there. The second best location was on top of the immediate rise to the east of the

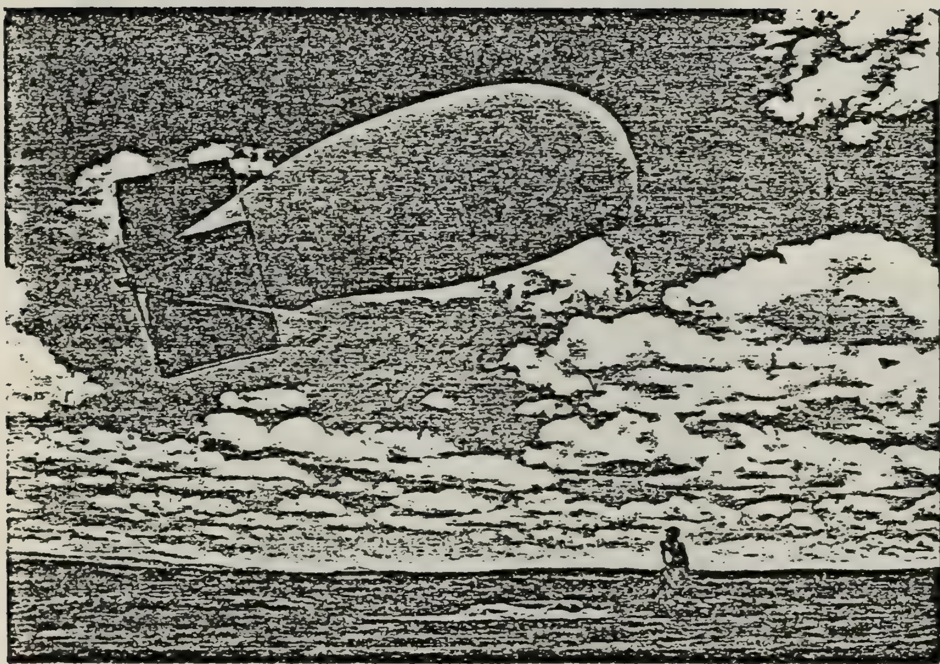

FIGURE 2-1. A Raven TRFD-1500 tethered balloon.

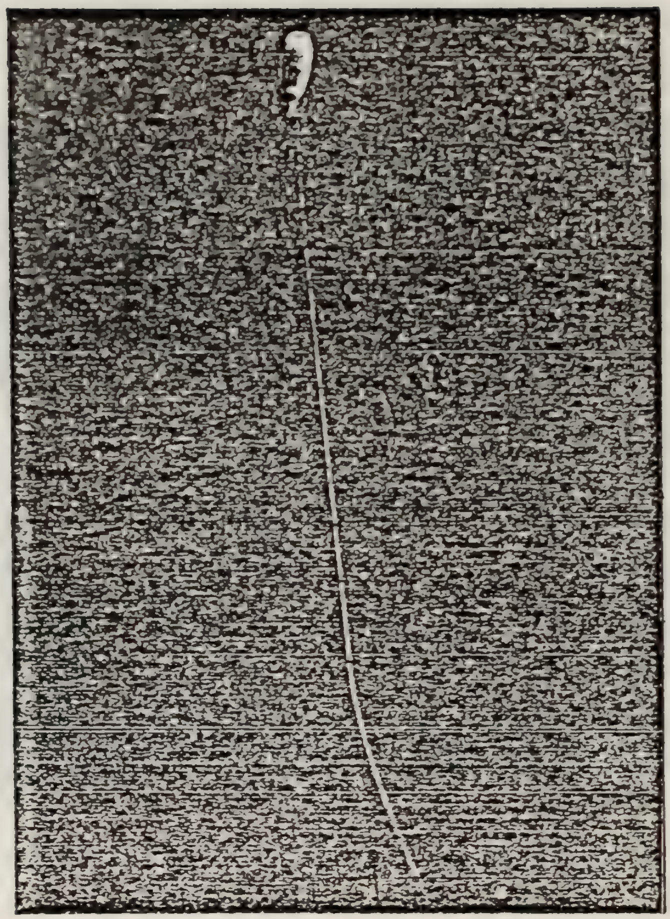

FIGURE 2-2. Release of SF_6 at 100 m above ground level. The tubing that carried the SF_6 was attached to the guy-wire of the tethered balloon.

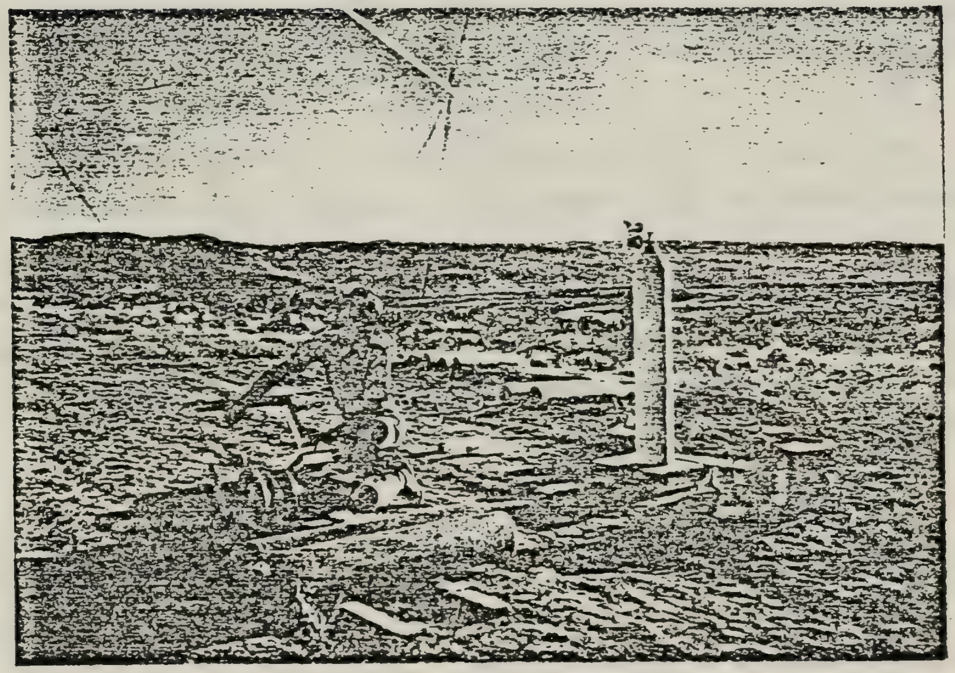

FIGURE 2-3. SF_6 was released from the bottle through a two-stage regulator and a rotometer. The bottle stood on an Accu-Weight Model 300T scale. To the left of the bottle is the motor-drive for regulating the height of the tethered balloon.

proposed facility because tracer gas released at this rise would be under the influence of the similar meteorological conditions affecting emissions from the ancillary facility and would thus be dispersed in a manner very similar to that of any emissions from the facility. Thus, during the experiment, SF_6 was released on top of the rise, as shown in Figure 2-4.

2.2 Tracer Gas Collection

To determine how far and where the tracer gas was transported after it was released, as well as how fast the tracer gas was dispersed, air samples were collected at a number of fixed and random locations throughout the tract and analyzed for SF_6 concentration.

There were a total of 23 fixed receptors, 22 of which are located in the expected downwind side of the SF_6 release point. Most of those receptors were placed on both sides of the Piceance Creek where maximum impact was likely. Three receptors were situated south of the release point to provide background data during the early morning hours. Figure 2-5 shows locations of fixed receptors, the release site, and the expected plume centerline. A fold-out map in the pocket located in the back cover of this report provides similar information on a larger scale.

At the fixed locations, samples were collected by automatic sequential syringe samplers fabricated by AV (Figure 2-6). The sampler consists of a turntable mounted on a gear reducer coupled to a speed controlled DC motor. Mounted onto the turntable are up to six removable 50 ml plastic syringes. Located next to the turntable is a stationary ramp. As the turntable rotates, the syringe plunger is fed into the ramp which is designed to pull the plunger completely out within one hour at a constant speed. Thus, up to six one-hour integrated samples can be collected sequentially and automatically by such an instrument. Thorough testing of the samplers under extreme temperature conditions (-10 to 50° C) has proven that a six-hour cycle is always completed within $\pm$ 1 minute of the correct period.

A valve is installed in the center of the turntable to seal off all of the syringe sampling openings from ambient air except for the one which is in the sampling mode.

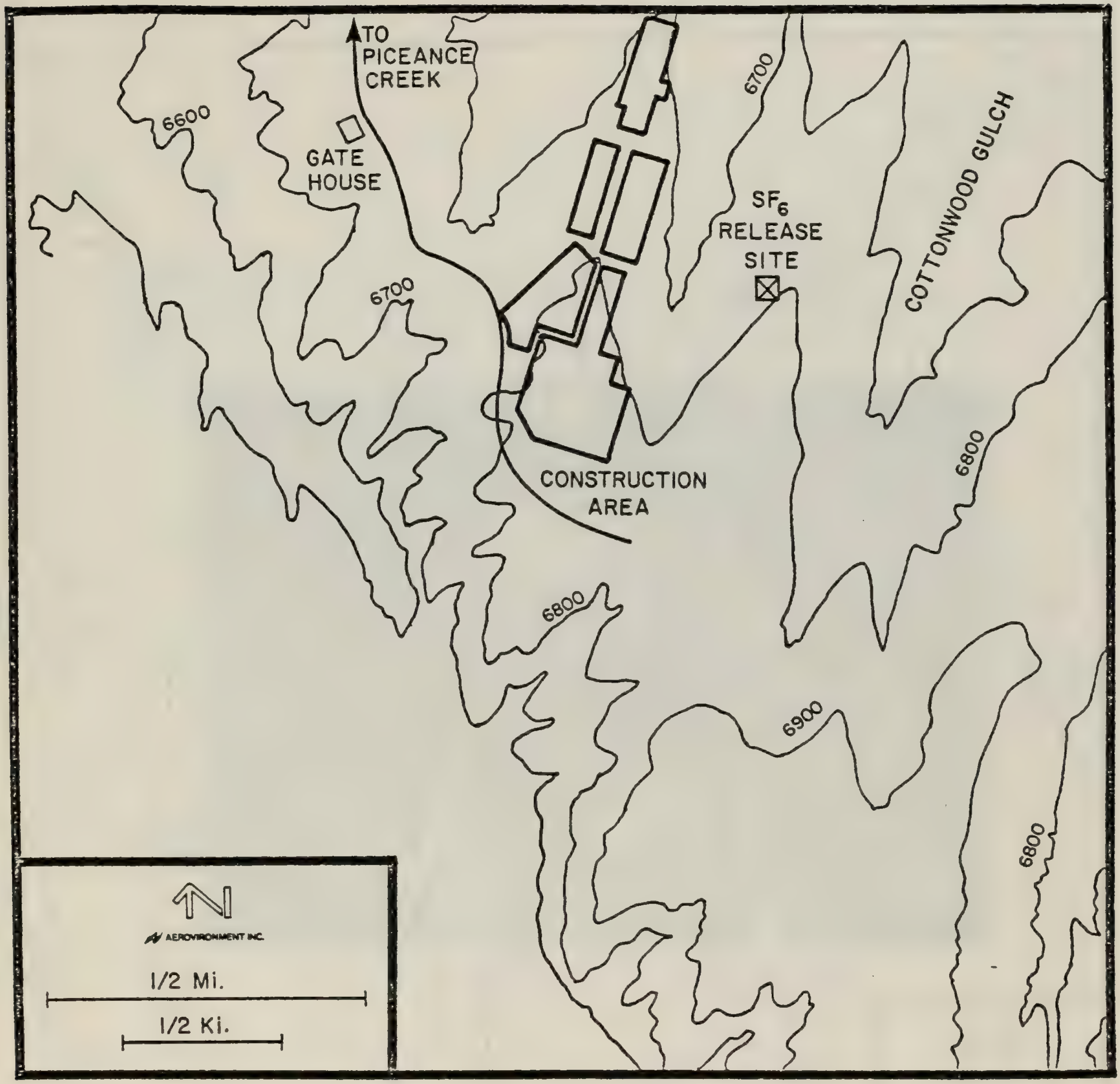

FIGURE 2-4. SF_6 release location in comparison to the site of the proposed ancillary facility.

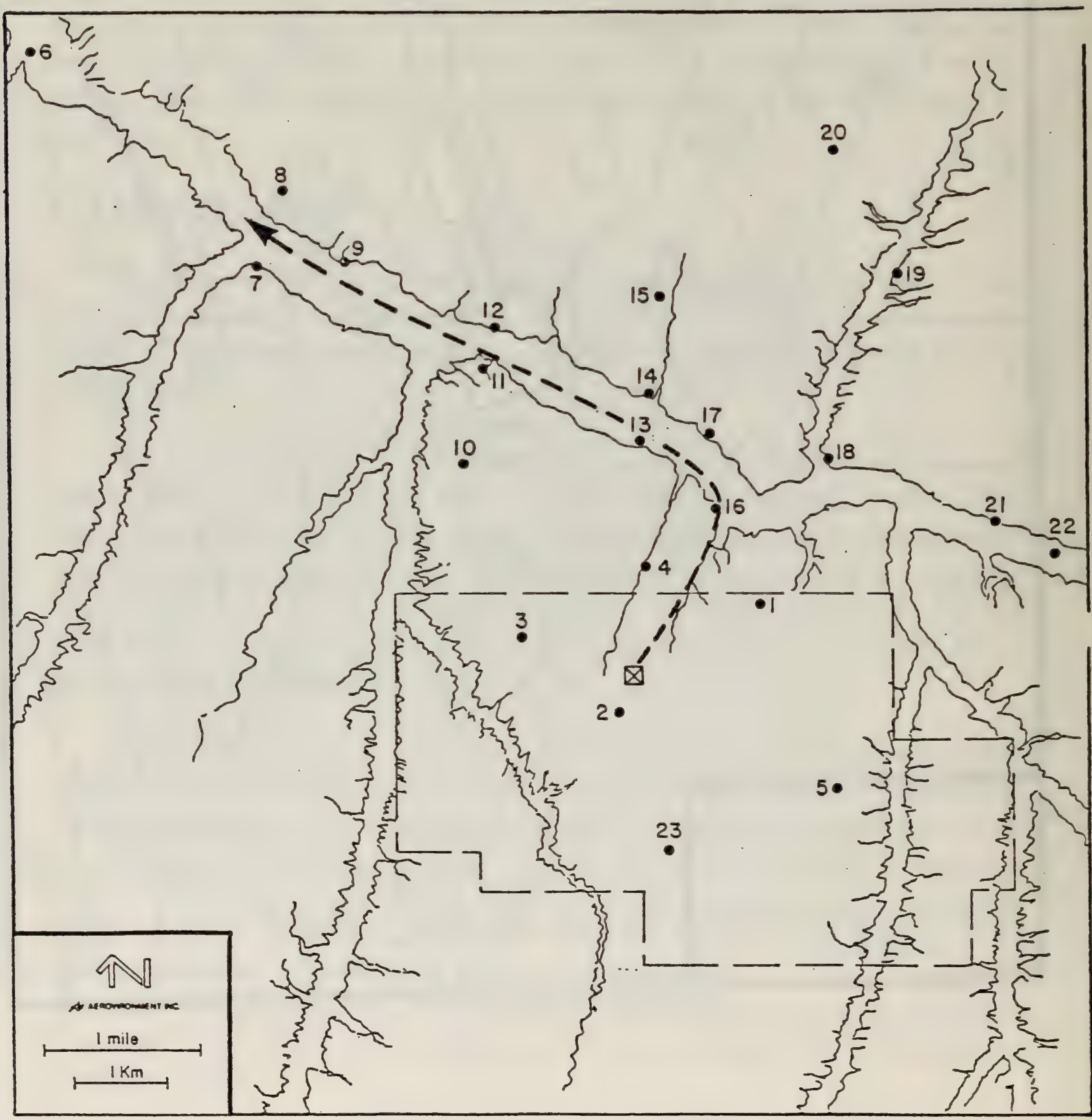

FIGURE 2-5. Locations of fixed sampler locations, SF_6 release site, and the expected plume trajectory in the early morning hours.

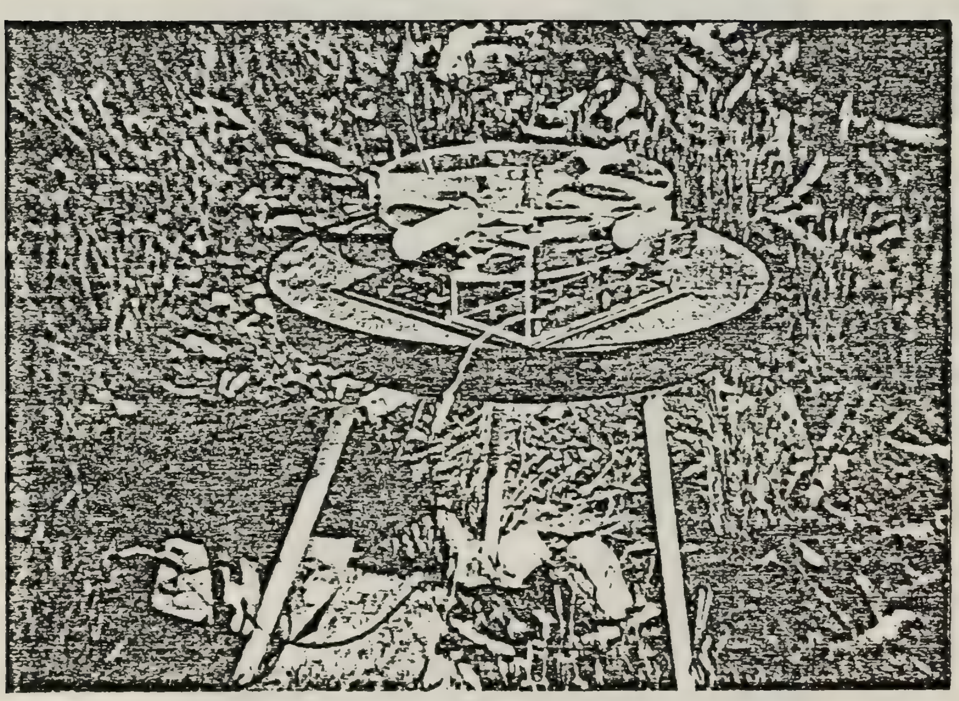

FIGURE 2-6. AV automatic sequential syringe sampler at work. One of the syringes has finished sampling, as indicated by the extended plunger, while another is in the sampling mode, as indicated by the plunger riding on the stationary ramp.

This design ensures that no diffusion would occur between the contents of the inactive syringes and the ambient air. At the end of a collection period, the syringes are removed manually and individually capped with specially designed plastic caps. Tests conducted prior to the actual experiment have shown that there is no measurable change in the conents of capped syringes within a 48-hour period.

At the random locations, grab samples were taken with plastic syringes. Figure 2-7 shows the collection of a grab sample during the experiment. The process consists of pulling out the syringe plunger very slowly. When the plunger is completely extended the syringe is sealed with a plastic cap. This process takes approximately 15 to 30 seconds.

2.3 Tracer Gas Analysis

The samples collected were analyzed for SF_6 by means of a System, Science & Software (S^3) Model 215 BGC Tracer Gas Monitor (Figure 2-8), an electron-capture gas chromatograph which was located in a nearby farmhouse which served as a temporary analysis laboratory shown in the map located in the back pocket of this report. The electron-capture gas chromatograph utilizes the high electron affinity of SF_6 with halogen group elements to provide a measurable signal.

Sulfur hexafluoride is not the only electron-capture gas to be contended with while making this measurement. Oxygen (O_2) also acts as a capture gas and will completely mask the SF_6 in its small concentration without a separation technique. Many halocarbons such, as members of the Freon family, will also give an electron-capture signal. Thus, an analytical column is used to separate the SF_6 from other electron capturing components and to slow down the O_2 molecules so that the SF_6 can pass through the detector ahead of the O_2.

The S^3 electron-capture gas chromatograph has a lower detectable limit of 1×10^{-12} parts concentration of SF_6 per part of air (ppt), is linear between 10^{-12} to 10^{-9}, and has a repeatability of better than or equal to 3%.

To insure the accuracy of the data, the instrument is calibrated using samples of known SF_6 concentrations ranging from 10^{-9} to 10^{-12} before, during, and after each analysis period.

FIGURE 2-7. Collection of a grab sample.

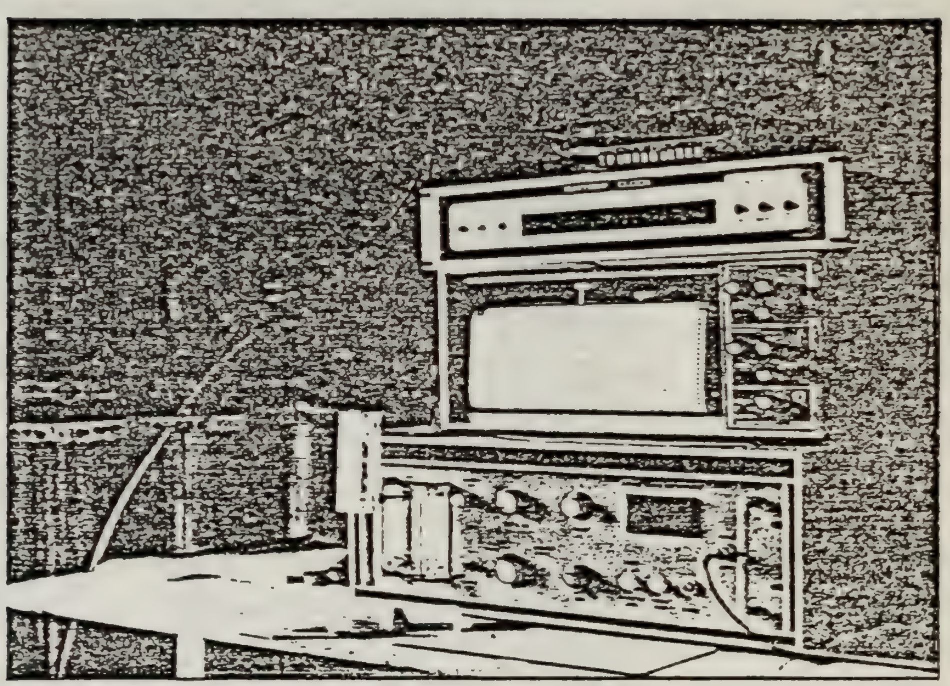

FIGURE 2-8. Systems, Science and Software Model 215 BGC tracer gas monitor.

2.4 Meteorological Measurements

A very important part of a model validation experiment is to characterize the meteorological conditions that transport and diffuse the tracer gas that is released. To achieve this, a network of meteorological equipment was set up on the tract. Surface wind speed and wind direction were measured continuously at eight locations, primarily along the expected plume trajectory. Temperature was also measured at seven of these sites. Their locations, as well as locations of other meteorological equipment are shown in Figure 2-9, as well as on the map in the back of this report.

In addition to measuring wind and temperature data at the surface (10 m above ground), wind speed and wind direction were measured at 30 m and 60 m at Site 023. Also measured at this site were turbulence information - the standard deviations of wind vane fluctuations and the standard deviations of vertical wind speed fluctuations (σ_θ and σ_w) at 10 m and the difference in temperature (ΔT) between 10 m and 60 m.

Vertical soundings of wind speed, wind direction, and temperature from ground surface to about 600 m above ground level were conducted hourly at Site 048, located in the Piceance Creek northwest of the release point. These soundings were made using a tethersonde system which includes an airborne sensor package, a balloon, an electric winch with line, and a ground receiving station. Figure 2-10 shows the tethersonde system at work.

Table 2-1 summarizes the meteorological measurements taken during the experiment. The range and accuracy of these instruments are presented in Table 2-2.

2.5 The Protocol

The experiment was performed on 14 and 15 September 1978 without any significant deviation from the original protocol (AeroVironment, 1978). The schedule of daily activities from the protocol is presented in Table 2-3.

On each of the two days, the experiment was begun at 0400 MDT, at which time SF_6 was released at 100 m above the top of the rise to the east of the proposed ancillary

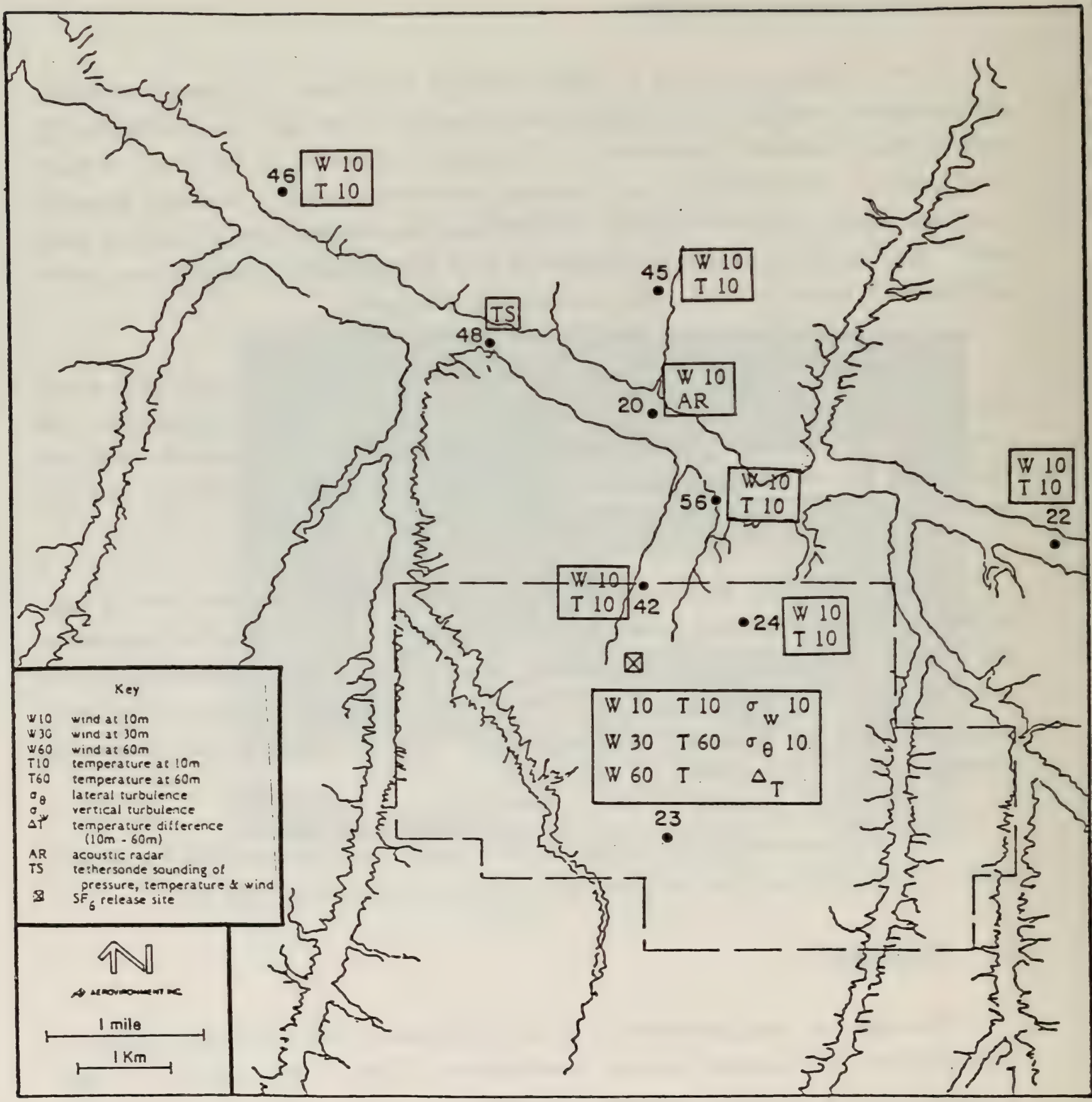

FIGURE 2-9. Locations of meteorological measurements.

FIGURE 2-10. The tethersonde sounding system at work. Temperature, wind speed, wind direction, and pressure were measured between ground and 1 km above ground level.

TABLE 2-1. Summary of meteorological measurements.

Site No.	Parameter	Equipment	Frequency
020	WS, WD Mixing height	WeatherMeasure W1034 AV Model 300A Acoustic Radar	continuous continuous
022	WS, WD, T	MRI 1071*	continuous
023	WS, WD (10m, 30m, and 60m) σ_θ (10m) σ_w (10m T (10m, 60m) ΔT (10m - 60m)	MRI 1074.2 MRI 1074.2 R. M. Young 27101 MRI 840 MRI 840	continuous continuous continuous continuous continuous
024	WS, WD, T	MRI 1022*	continuous
042	WS, WD, T	MRI 1071	continuous
045	WS, WD, T	MRI 1071*	continuous
046	WS, WD, T	MRI 1071*	continuous
048	T, Tw, WS, WD, P	Tethersonde TS-2A*	two soundings per hour
056	WS, WD, T	MRI 1071	continuous

*equipment specifically installed for tracer study.

TABLE 2-2. The range and accuracy of meteorological instruments used in the experiment.

Instrument	Parameters Measured	Range	Accuracy
WeatherMeasure W1034 wind system	wind direction wind speed	0 to 540^{o} 0 to 45 m/s	$\pm$ 5^{o} $\pm$ 0.5 m/s
MRI 1071 mechanical weather station	wind direction wind speed temperature	0 to 360^{o} 0.5 to 55 mph -34 to 49 C	$\pm$ 5^{o} $\pm$ 1 m/s $\pm$ 1.5 C
MRI 1074.2 wind system	wind direction wind speed	0 to 540^{o} 0 to 45 m/s	$\pm$ 5^{o} $\pm$ 0.2 m/s
MRI 1022 wind system	wind direction wind speed	0 to 540^{o} 0 to 45 m/s	$\pm$ 3^{o} $\pm$ 0.2 m/s
AV Sigma (σ_w) computer	r.m.s. vertical wind fluctuation	0 to 1 m/s	$\pm$ 0.05 m/s
MRI 840 temperature sensor	temperature	-50 C to 50 C	$\pm$ 0.10 C
AV 300A Acoustic Radar	mixing height	20 m to 1000 m	$\pm$ 20 m
Atmospheric Instrumentation Research Tethersonde	wind direction wind speed temperature pressure	0 to 360^{o} 0.5 to 20 m/s -50 to 50 C 0 to 100 millibar	$\pm$ 5^{o} $\pm$ 0.25 m/s $\pm$ 0.5 C $\pm$ 1 millibar

TABLE 2-3. Schedule of daily activities on 14 and 15 September 1978.

Time	Activity
0400 MDT	Begin SF_6 release from a kytoon 100 m above ground. Field technicians deployed to the predetermined sampling points to set up samplers.
0500	Tethersonde sounding.
0600	Beginning of first one-hour air sample collection. Tethersonde sounding.
0700	Beginning of second one-hour air sample collection. Tethersonde sounding.
0800	Beginning of third one-hour air sample collection. Tethersonde sounding.
0900	Beginning of fourth one-hour air sample collection. Tethersonde sounding.
1000	Beginning of fifth one-hour air sample collection. Tethersonde sounding.
1100	End of air sample collection. Tethersonde sounding. SF_6 release shut off. Field technicians collect samplers, take them to field office, remove syringes and install new syringes.
1200	Sample syringes taken to nearby farmhouse.
1300	Beginning of SF_6 analyses of samples.

facility. The release was continued through 1100 MDT at a constant rate of approximately 3 g/s (28 lb/hr).

Ambient air sampling was commenced at 0600 by use of automatic sequential syringe samplers at 23 fixed locations. Sampling was not begun until two hours after the release was under way, assuring that a quasi-steady state had been attained. Five consecutive one-hour integrated air samples were collected at these locations through 1100 MDT. These locations were shown earlier in Figure 2-5.

In addition to collecting samples at these fixed locations, 61 grab samples were taken at locations shown in Figure 2-11 on 14 September, and 67 grab samples were taken at locations shown in Figure 2-12 on 15 September.

During the test period, meteorological measurements discussed in Section 2.4 were activated. Measurements included wind speed, wind direction, temperature, temperature difference etween 10 m to 60 m, turbulence, mixing height, and vertical profiles of temperature, wind speed, wind direction, and pressure.

At the end of each test day, air samples were taken to the nearby farmhouse about two miles northwest of the tract and were analyzed for SF_6 by use of an electron capture gas chromatograph.

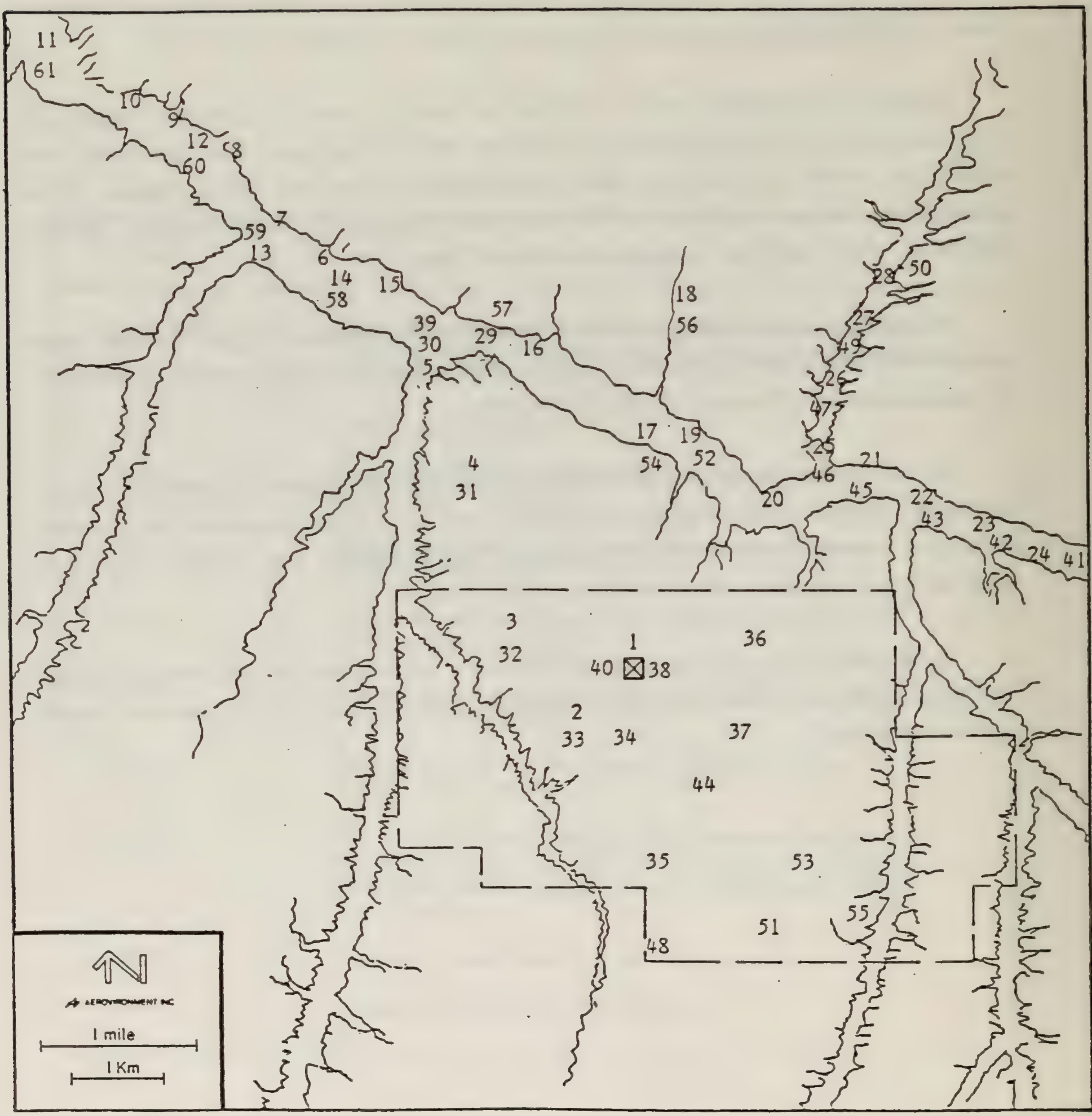

FIGURE 2-11. Locations of grab samples taken on 14 September 1978.

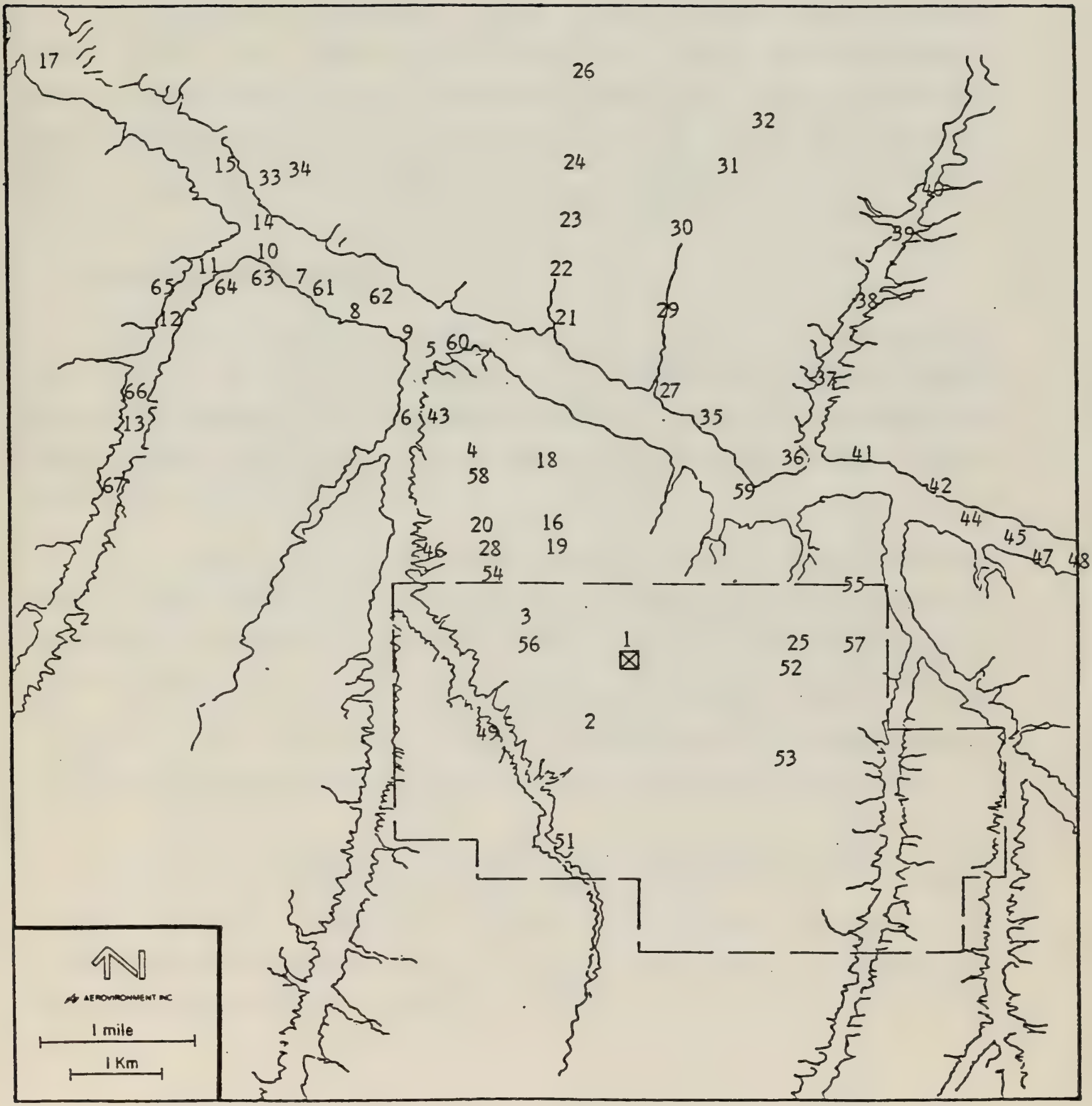

FIGURE 2-12. Locations of grab samples taken on 15 September 1978.

3. RESULTS

To understand the distribution of tracer gas concentrations, one has to first understand the factors affecting such a distribution – namely, the meteorological conditions that existed during and immediately preceding the release of tracer gas. Section 3.1 discusses the synoptic weather situation on the days of the experiment. Section 3.2 presents the meteorological conditions observed over the tracts during the experiment while Sections 3.3 and 3.4 present the tracer gas data.

3.1 Synoptic Weather Situation

After a frontal passage on September 11, a closed upper-level low formed north of Tract C-b. By the morning of September 14, a general northeast-southwest trough situation had developed from Manitoba to Nevada (see Figure 3-1). Two distinct low pressure centers were centered in these areas with Colorado in between. Pressure gradients became weak over the tract.

After sunrise on the 14th, an anomalous blocking pattern with a warm high over Western Canada formed. By the morning of the 15th (Figure 3-2) a fast west-east jet stream had set up along the U.S.-Canadian border. At the surface a rapidly moving, weak, dry front passed mainly south of the tract during the afternoon and early evening of the 14th. Clouds from this system cleared away shortly after midnight but the pressure maintained its weak pattern. By the afternoon of the 15th, clouds and a strong southwest flow preceding another weather front were becoming established over the tract area.

The weak pressure gradients and the lack of clouds allowed the formation of strong drainage, particularly along Piceance Creek, on the morning of September 14. Although clouds formed during the afternoon of September 14, they cleared away shortly after midnight, allowing radiative cooling of the ground to take place. The drainage that developed on the morning of September 15, however, was much weaker than that of the 14th.

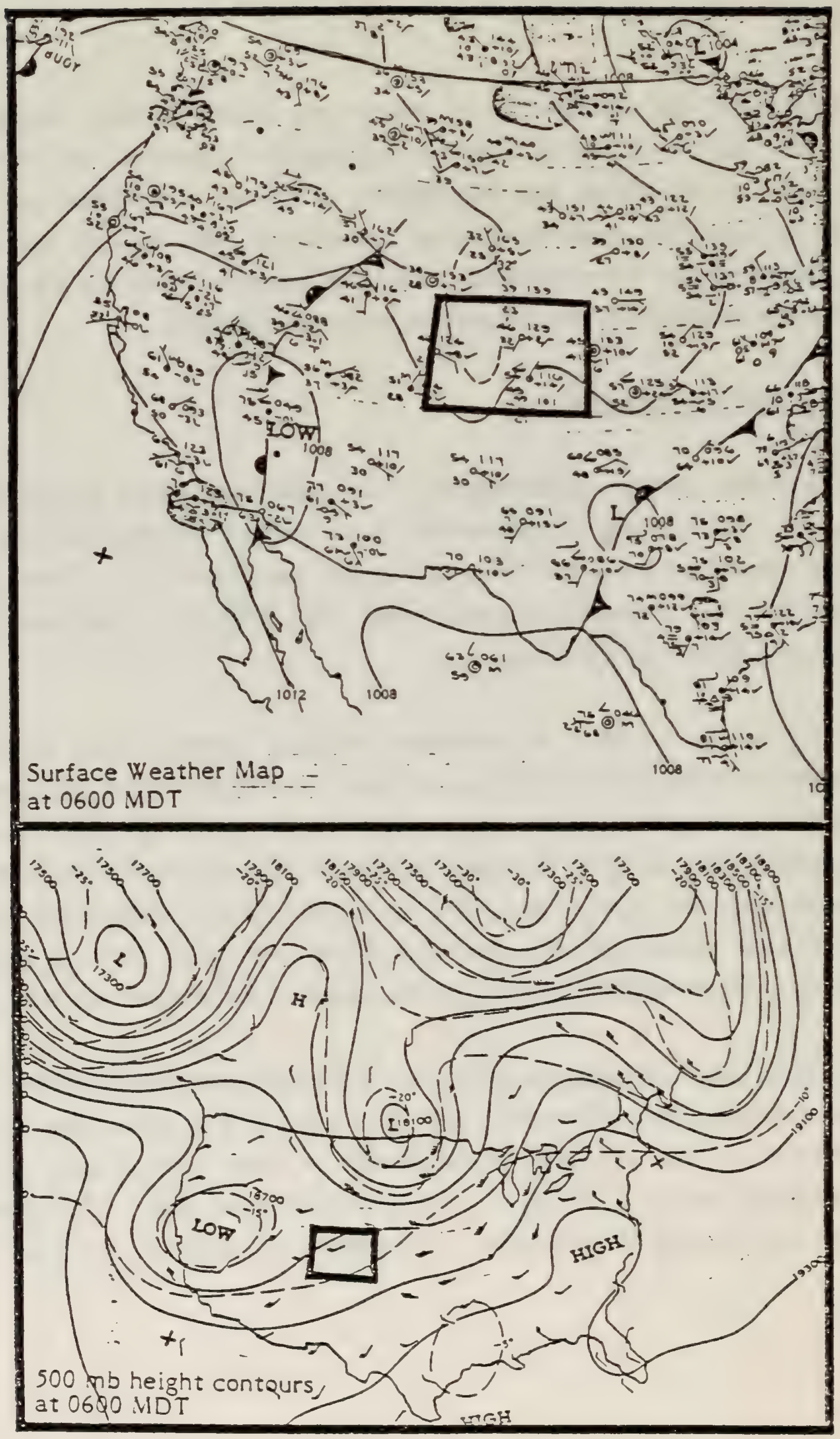

FIGURE 3-1. Synoptic weather situation on 14 September 1978.

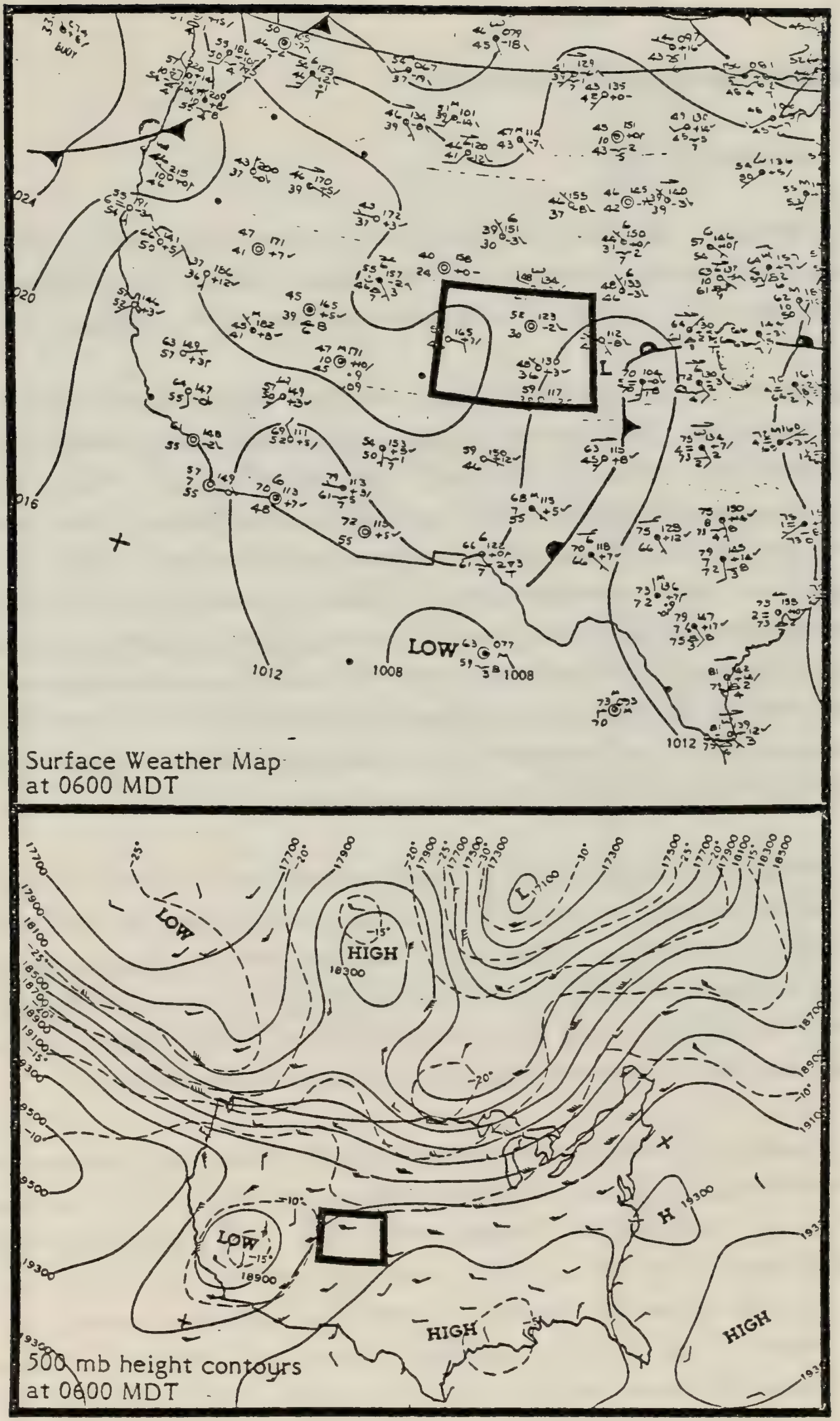

FIGURE 3-2. Synoptic weather situation on 15 September 1978.

3.2 Meteorological Conditions on C-b Tract

- 14 September 1978

The atmospheric structure over Piceance Creek as well as over the entire tract is best illustrated by soundings taken at Site 048. Data collected during the soundings are presented in Appendix A. Figure 3-3 shows three such soundings of temperature.

As a result of strong radiative cooling, a very deep surface-based inversion appeared in the pre-dawn hours. This inversion was quite strong close to the surface but gradually weakened until about 500 m AGL, when it became isothermal. This situation was observed in soundings through 0700 MDT. Beginning at about 0800 MDT, the inversion lost more of its strength and the base of the isothermal layer lowered to about 350 m AGL. The destruction of the surface-based inversion began at about 0900 MDT and the top of the isothermal layer was detected at about 450 m AGL. This isothermal layer was topped by a neutral lapse layer. Further destruction of the surface-based inversion and lowering of the base of the neutral lapse layer continued until about 1100 MDT, when the inversion totally disappeared and was replaced by a neutral lapse condition. Similar conclusions could be derived from data collected by the acoustic radar at Site 020.

This atmospheric structure would, of course, apply only along the Piceance Creek. However, one can infer that a surface-based inversion did exist over the entire tract, even on the ridges and above the release site. This inference is supported by the delta-temperature data collected at Site 023 as well as by tethersonde profiles taken over the tract at various locations in 1976 (C-b Shale Oil Venture, 1976). Figure 3-4 shows what the constant potential temperature surfaces should look like over the tract.

The soundings at Site 048 also provided valuable information concerning the wind flow above the Piceance Creek. Strong drainage was evident, with the maximum speed appearing shortly after 0600 MDT at about 150 m AGL. The synoptic flow pattern was not observed below about 600 m AGL in the early morning hours. As the morning advanced, the heat gained by the surface from solar radiation exceeded that lost by terrestrial radiation and the soil temperature rose, warming the air just above. This created pressure differences resulting in an upslope flow. The evidence of this upslope

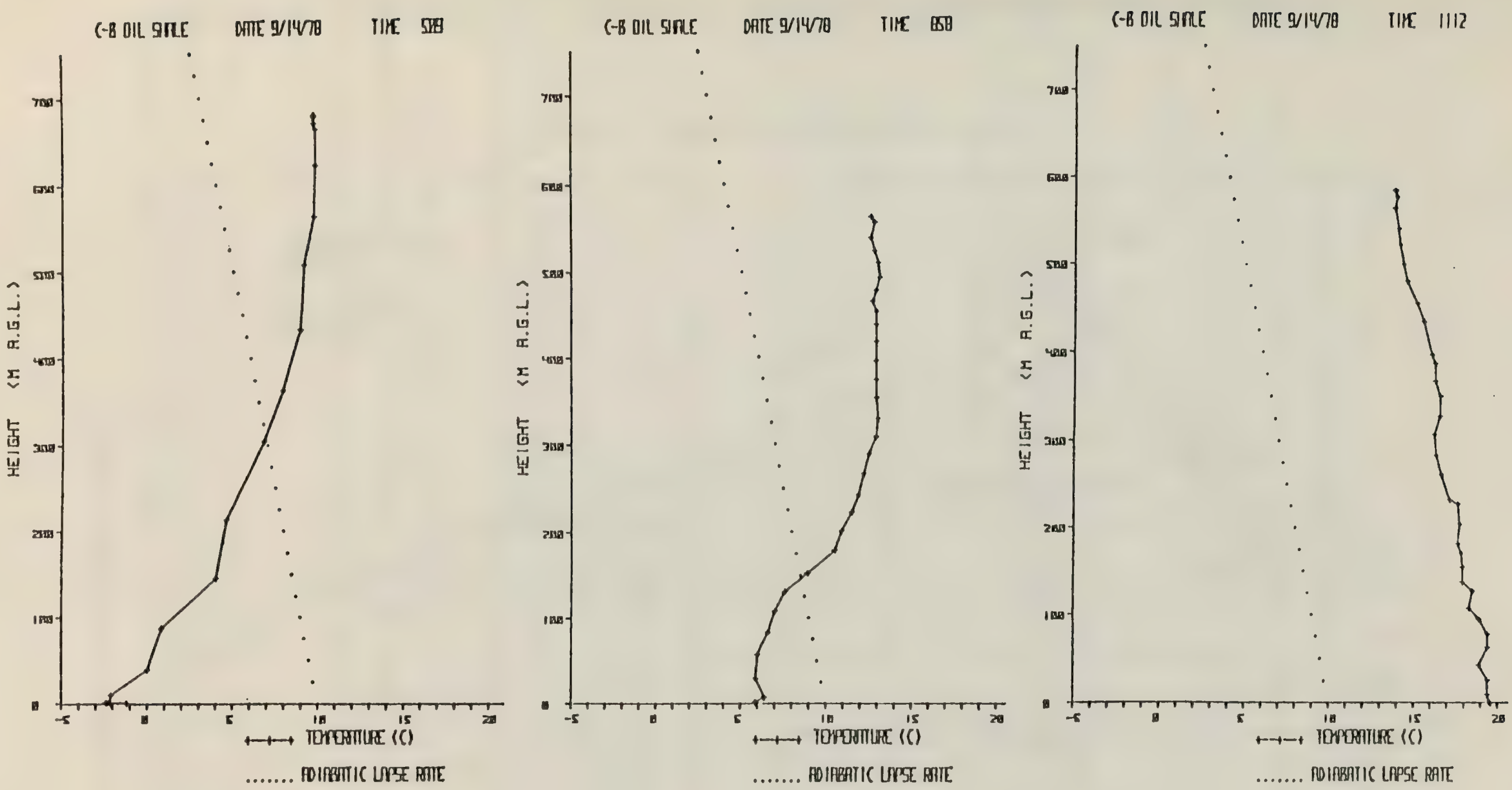

FIGURE 3-3. Temperature soundings taken on 14 September 1978.

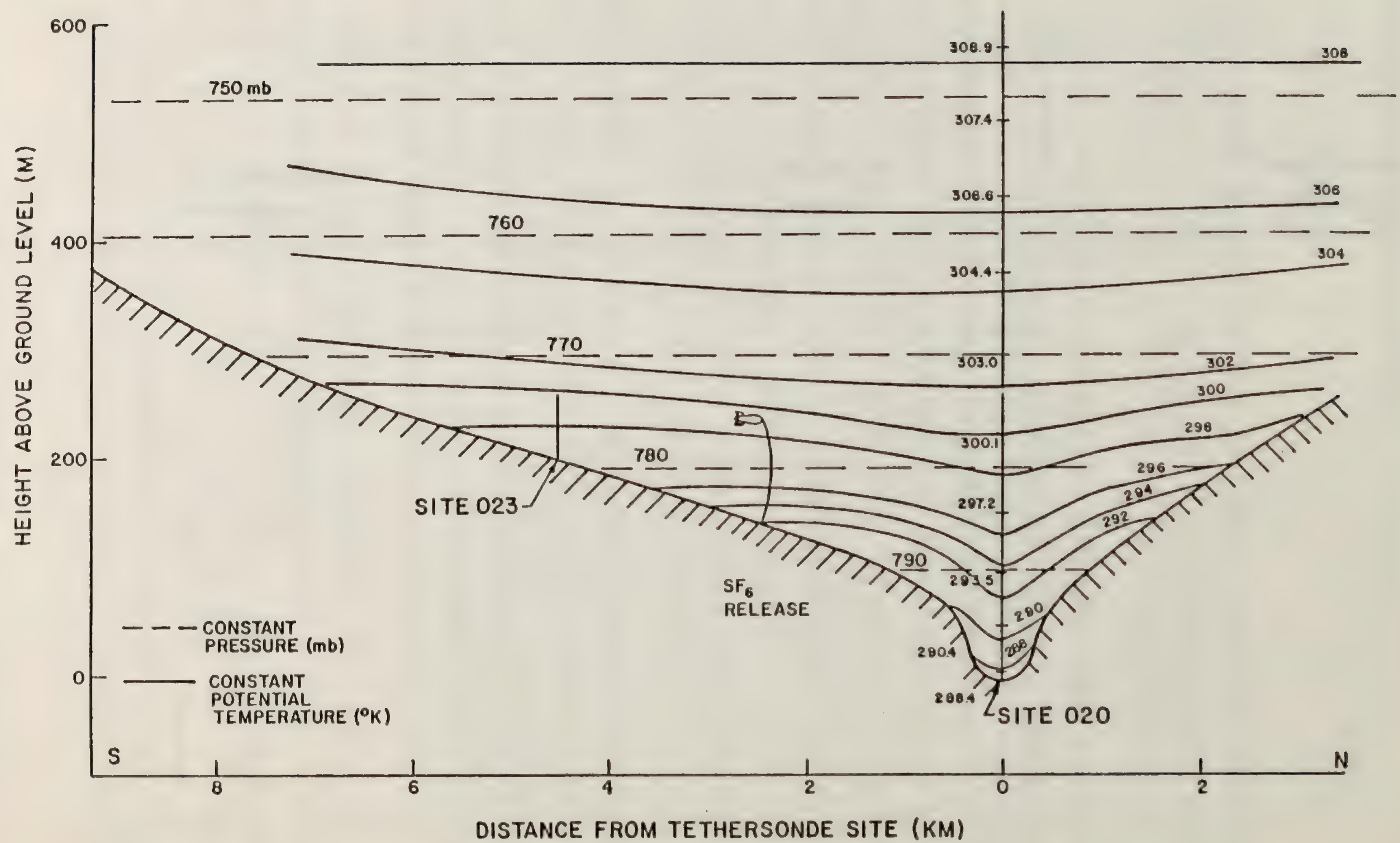

FIGURE 3-4. Constant potential temperature surfaces constructed from sounding taken at Site 048 on the morning of 14 September 1978.

flow showed up at about 0900 MDT. At this time there were still remnants of the nighttime drainage on top of this newly developed upslope flow. The strongest shear appeared at around 200 m AGL. It was not until the end of the experiment, around 1100 MDT, that the drainage flow system was totally destroyed. Even at 1100 MDT, there was still a surface layer of upslope flow to about 150 m, above which existed the synoptic flow. This wind flow picture is illustrated in Figure 3-5. It is interesting to note that at about 300 m AGL, the wind speed was virtually zero at 0600-0700 MDT, the first hour of the sampling period.

The wind flow over the rest of the tract (other than over Piceance Creek) followed a similar pattern. Strong drainage prevailed between 0400-0600 MDT. Figure 3-6 shows streamlines of the drainage situation while Figure 3-7 shows what the drainage looks like in a cross-section between Sites 023 and 020.

During the first hour of sampling, the overall pattern was still of the drainage type although almost calm conditions were detected at various locations over the tract. At the release site, the kytoon was observed to head towards the west, then rotated clockwise during the hour to finally end up pointing towards the south-southeast direction.

The second hour of sampling saw the head of the kytoon meandering between south-southeast to east. In other words, the wind at the level of release was from the south-southeast to east. Over other parts of the tract, the wind was light and often variable, with the predominant direction from the eastern sector. This is probably due to the fact that the tract is located west of the Continental Divide and in the macroscale, there would be a drainage that flows generally from east to west over the tract.

Between 0800-0900 MDT, the wind at the point of release, as indicated by the heading of the kytoon, was from the southeast to east. Meteorological data from other wind stations indicated that the wind was still light and variable, without a definitely organized flow system.

During the last two hours of the sampling period, the heading of the kytoon indicated that the wind at the point of release was from the north to east quadrant. Data collected also indicated that the wind was generally from the north in areas south of the

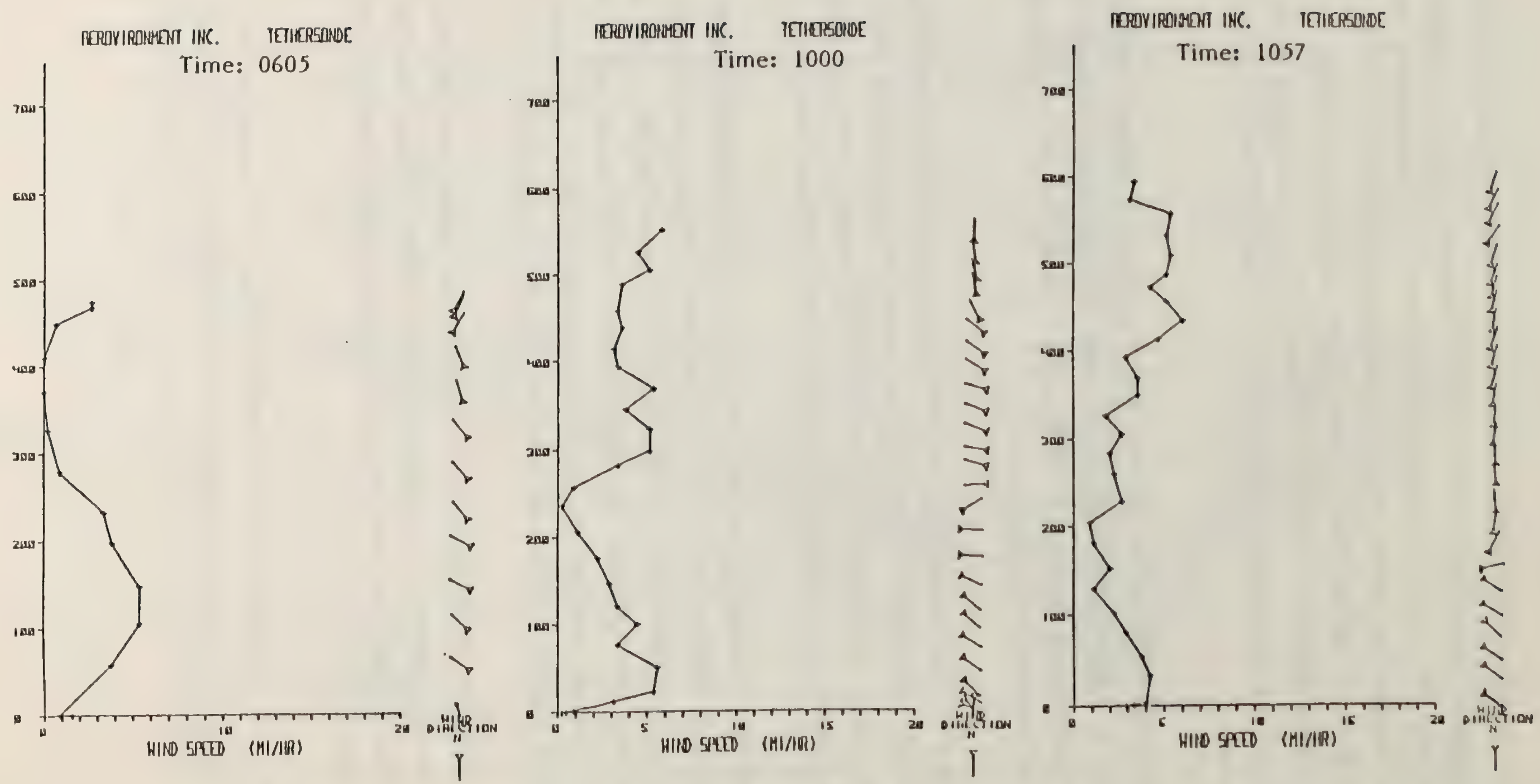

FIGURE 3-5. Wind soundings taken on 14 September 1978.

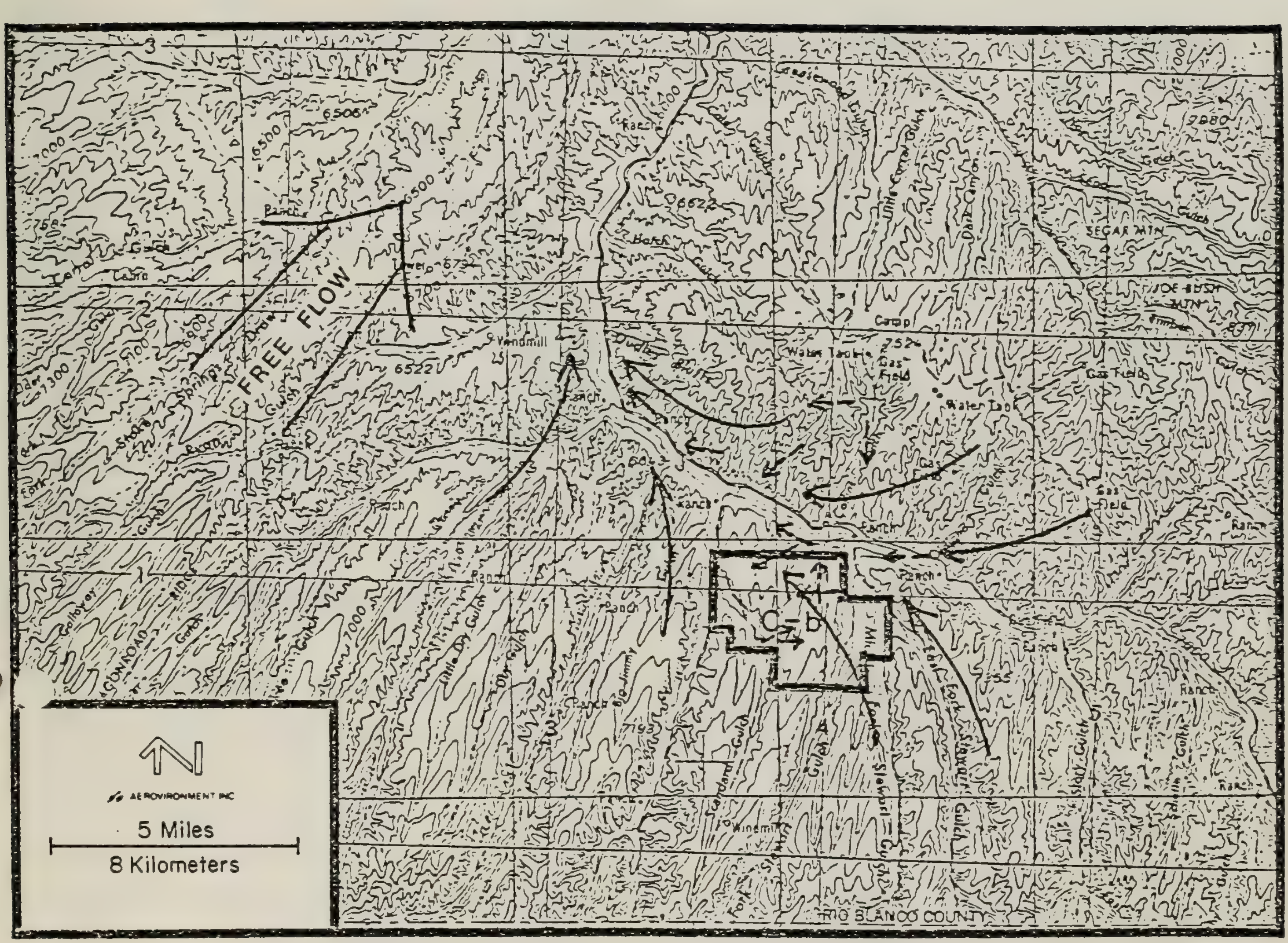

FIGURE 3-6. Streamlines of drainage situation over Tract C-b.

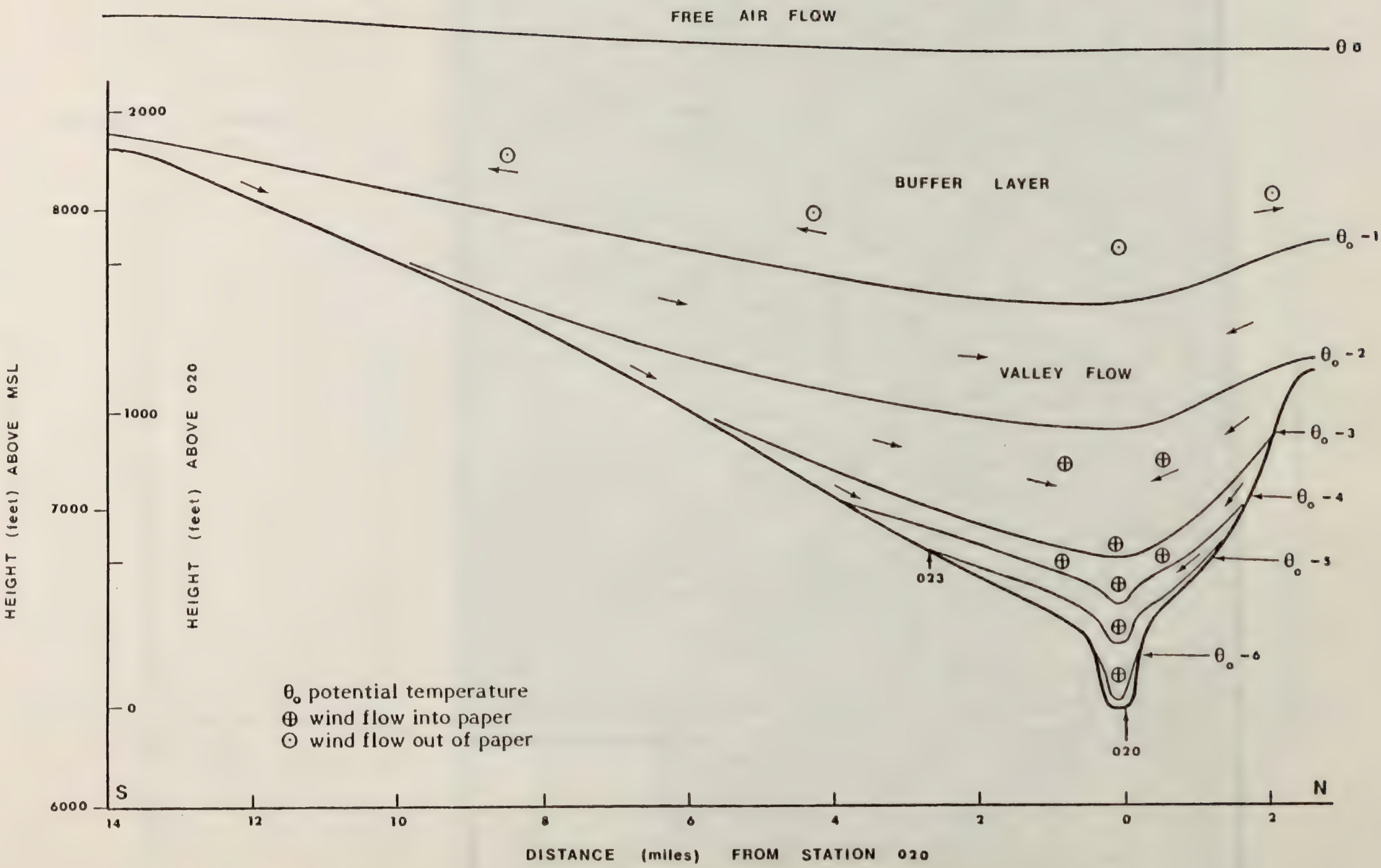

FIGURE 3-7. A cross-sectional view of the drainage flow.

Piceance Creek and from the south from areas north of the Piceance Creek. This phenomenon is generalized in Figure 3-8 and Figure 3-9.

The synoptic flow (winds from the south) was never established at the surface during the sampling period. It appeared around noon. Figure 3-10 shows a picture of the synoptic pattern in the afternoon.

Data collected at Site 023 showed that turbulence was weak throughout the period of sampling, especially between 0600-0800 MDT.

In summary, during the first three hours of sampling drainage was evident along Piceance Creek and the gulches leading to Piceance Creek. Over the ridges and higher ground, the surface flow was disorganized and weak. In the last two hours of sampling, an upslope flow was discernible all over the tract. Turbulence was weak, especially between 0600-0800 MDT.

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The temperature soundings taken during the early morning hours showed a surface-based radiation inversion. However, as discussed in Section 3.1, the weak front that passed over the tract in the previous afternoon and the clouds associated with the front resulted in an inversion that was shallower and weaker than the one during the previous morning. A neutral lapse rate existed above about 500 m AGL at 0600 MDT. The effect of surface heating was also detected an hour earlier than on 14 September. The destruction of the surface-based inversion was observed at 0800 MDT, at which time the base of the neutral-lapsed layer was at about 400 m AGL. By 0900 MDT, the entire layer above the ground had attained an adiabatic structure.

The changes in wind flow in the vertical related very well to the temperature structure. Within the inversion layer, a drainage condition existed. Above the inversion, the synoptic flow pattern was obvious. Immediately following the onset of surface heating, wind in the layer closest to the ground became weak. At 0900 MDT, the wind in the bottom 200 m was almost calm. Shortly thereafter, the wind speed began picking up and by 1100 MDT, the wind in the entire layer averaged about 5 m/s. There was no evidence of any upslope wind flow pattern.

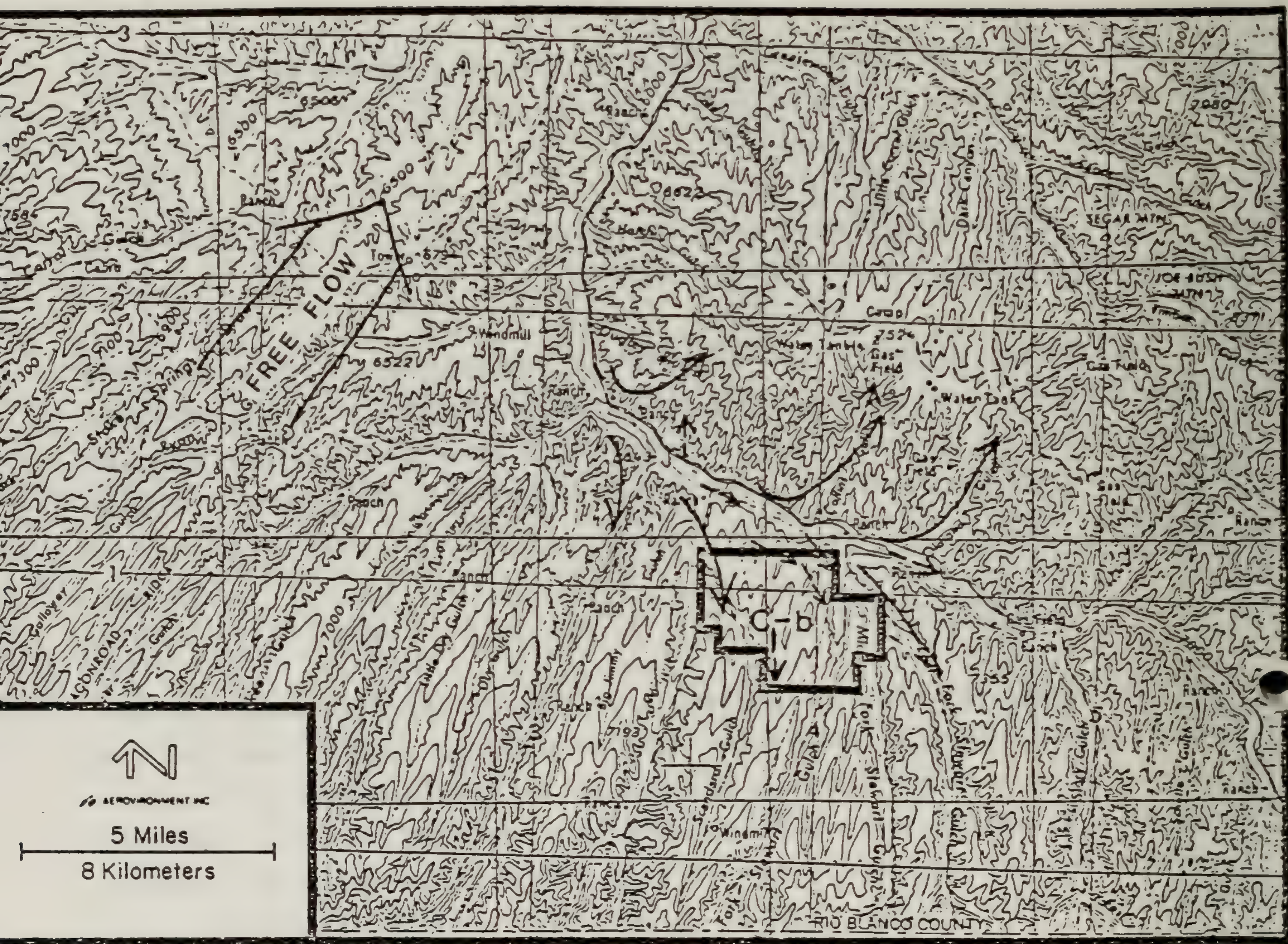

FIGURE 3-8. Streamlines of upslope flow over Tract C-b.

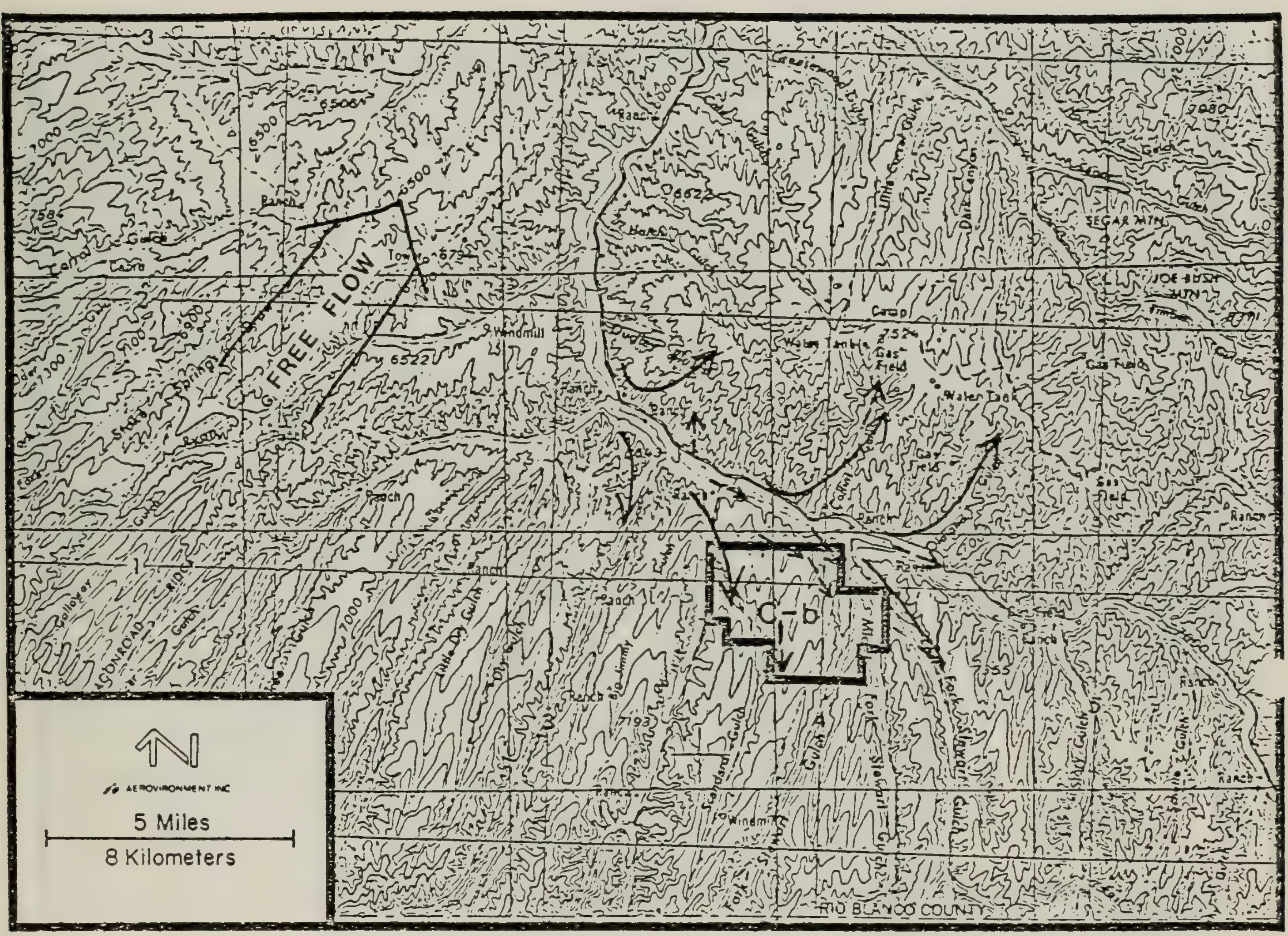

FIGURE 3-8. Streamlines of upslope flow over Tract C-b.

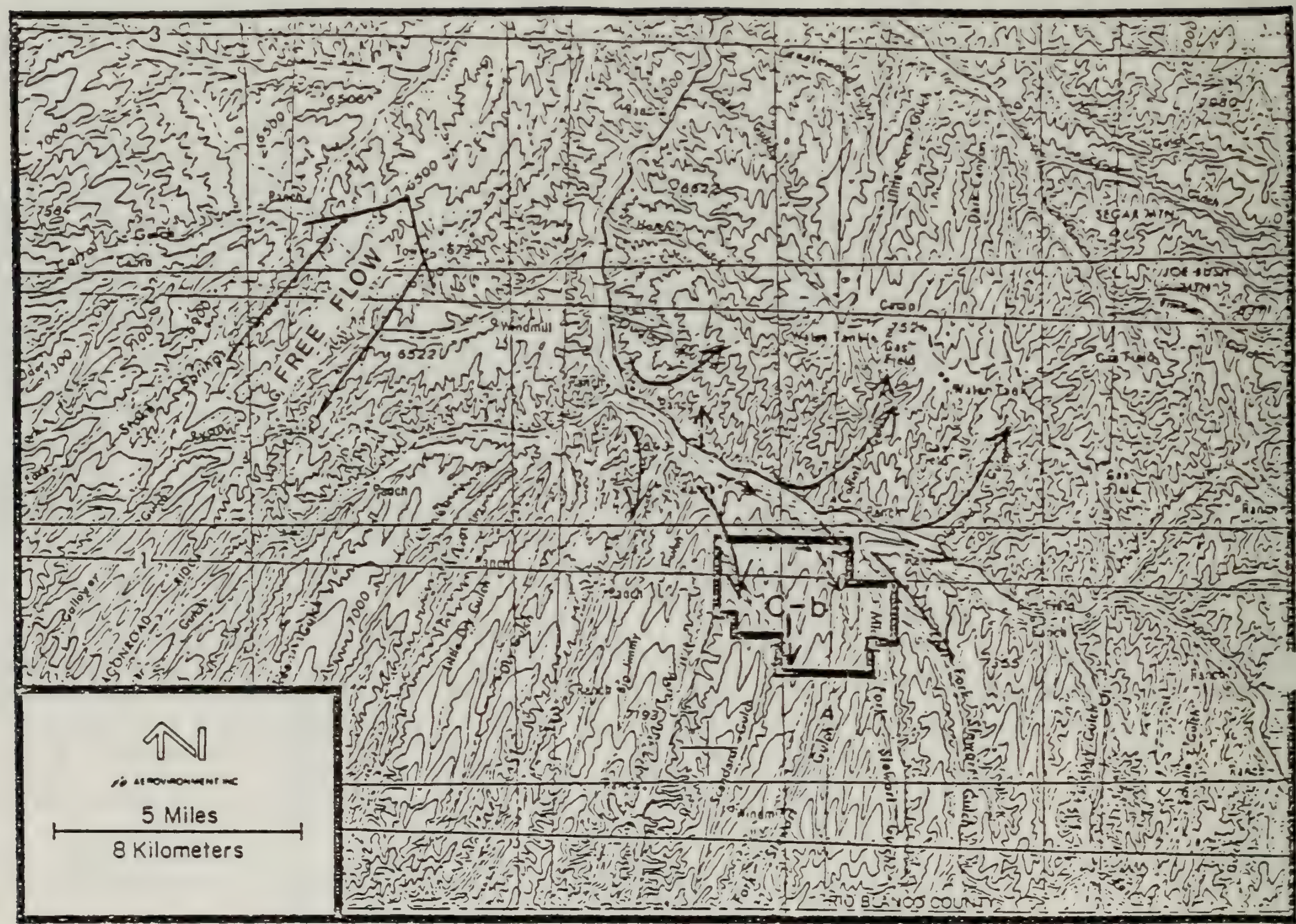

FIGURE 3-8. Streamlines of upslope flow over Tract C-b.

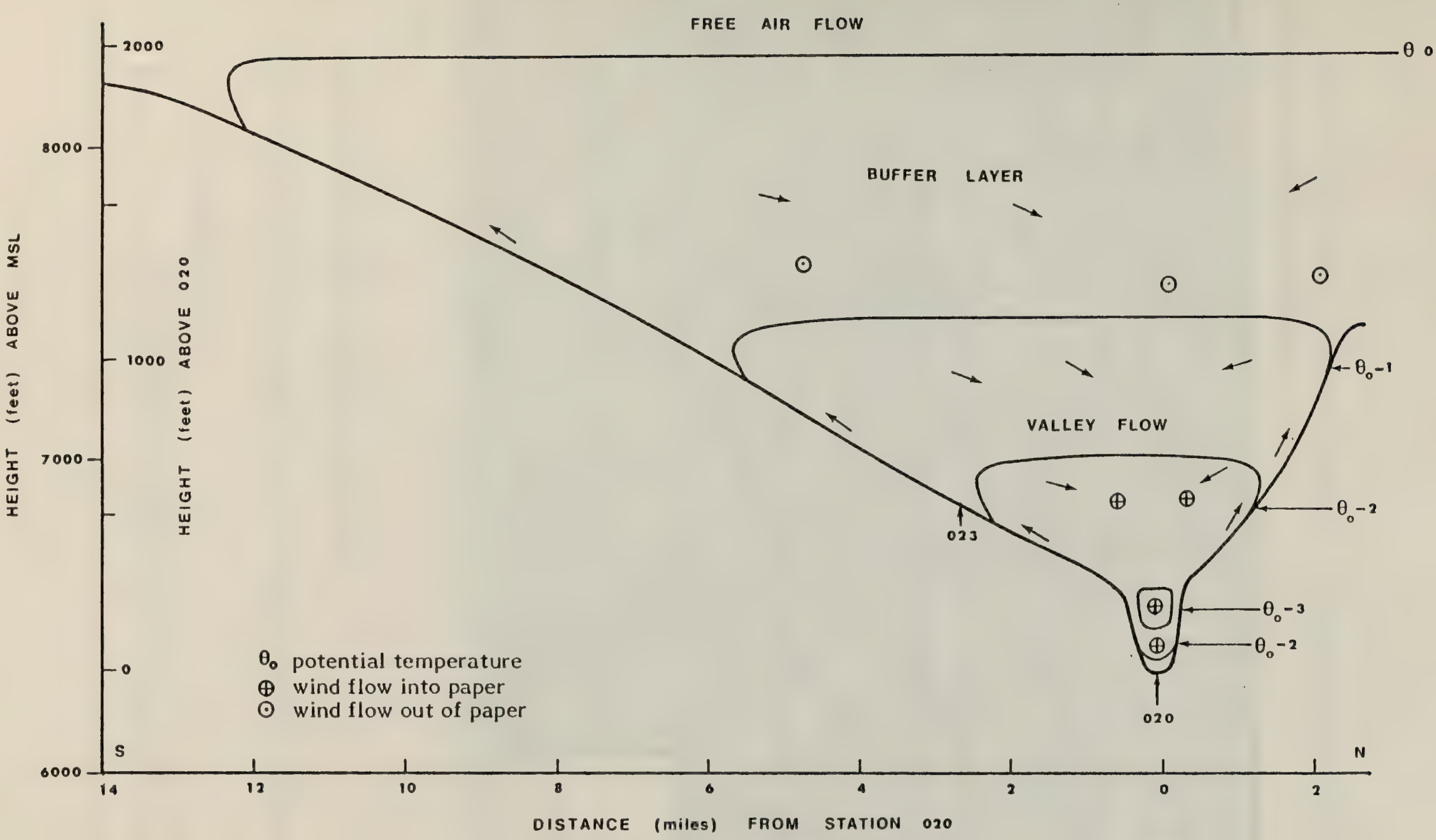

FIGURE 3-9. A cross-sectional view of the upslope flow.

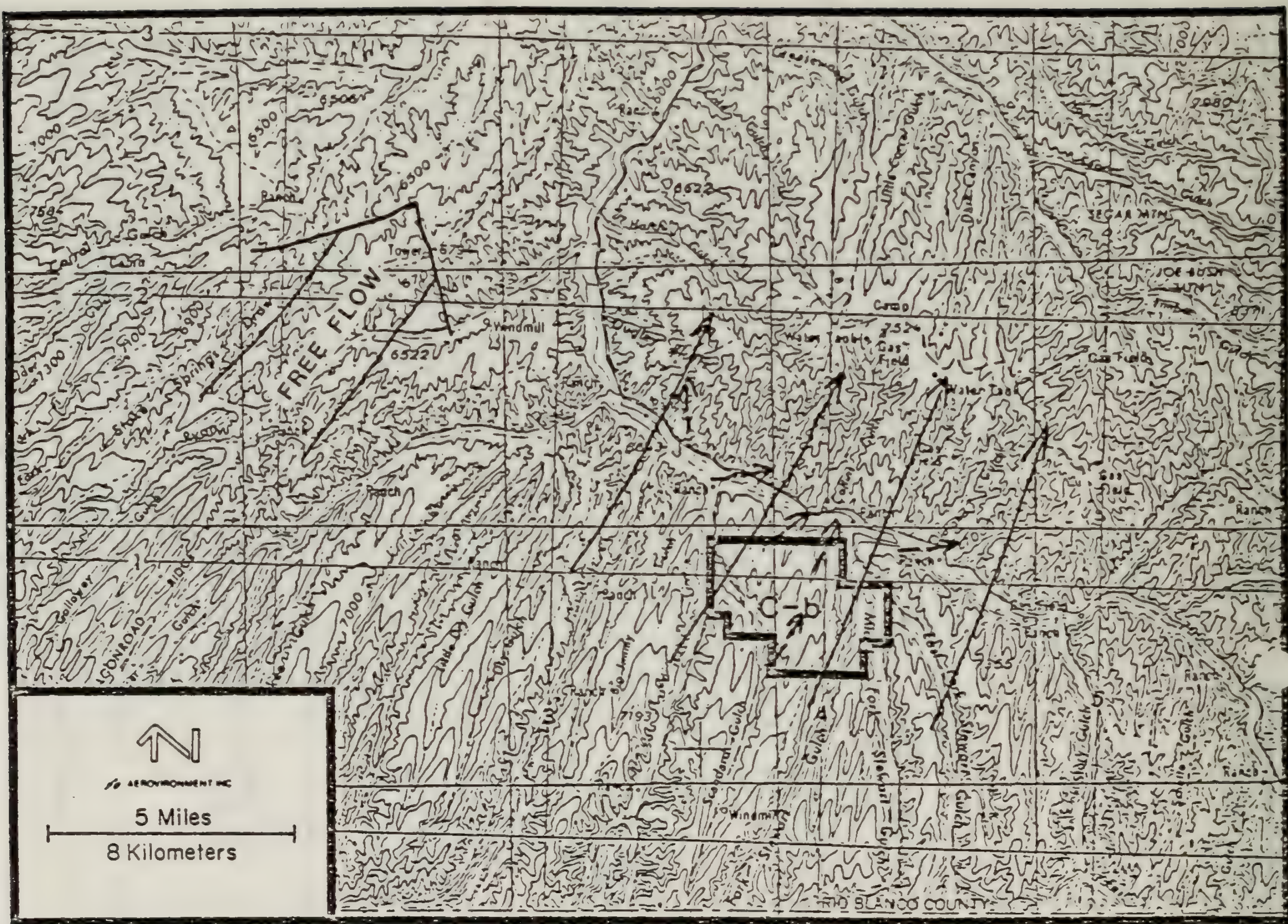

FIGURE 3-10. Streamlines of synoptic flow over Tract C-b.

Figures 3-11 and 3-12 show the progression of temperature and wind soundings respectively during the experiment.

At the release site, the orientation of the kytoon indicated that the wind was from the southeast to east sector starting at 0400 MDT through 0900 MDT. During the hour beginning at 0900 MDT, the kytoon indicated that the wind was mostly from the south to southwest sector with a short period with winds coming out of the northwest. The wind was from the southwest during the first half of the last hour of SF_6 release and from the south-southwest during the second half of the last hour at the point of release.

Wind data at other sites showed that the wind was from the north to east quadrant on the ridges between 0600-0800 MDT and from the western quadrant between 0800-0900 MDT. Thereafter, all surface data, including wind observations in Piceance Creek, showed evidence of the synoptic wind flow pattern, generally from the south-southwest.

In summary, there was a drainage system over the tracts prior to 0800 MDT. Between 0800-0900 MDT, there was a transition from the drainage to synoptic flow and the synoptic flow took control after 0900 MDT. The wind, as well as turbulence, was stronger than the previous day, especially before 0800 MDT.

3.3 Tracer Gas Release Data

The actual release data is presented in Appendix B. The release rate was kept fairly constant during the experiment, at about 3.21 g/s (28.8 lb/hr) in the first day and 3.14 g/s (28.0 lb/hr) in the second day. The height of release was approximately 100 m (330 ft) AGL.

3.4 Distribution of Ground Level SF_6 Concentration

The actual observed SF_6 concentrations at all sites are presented in Appendix C.

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Figures 3-13 through 3-17 show isopleths of SF_6 constructed from observed data. Downwind of the plume there were several places without observations, which made

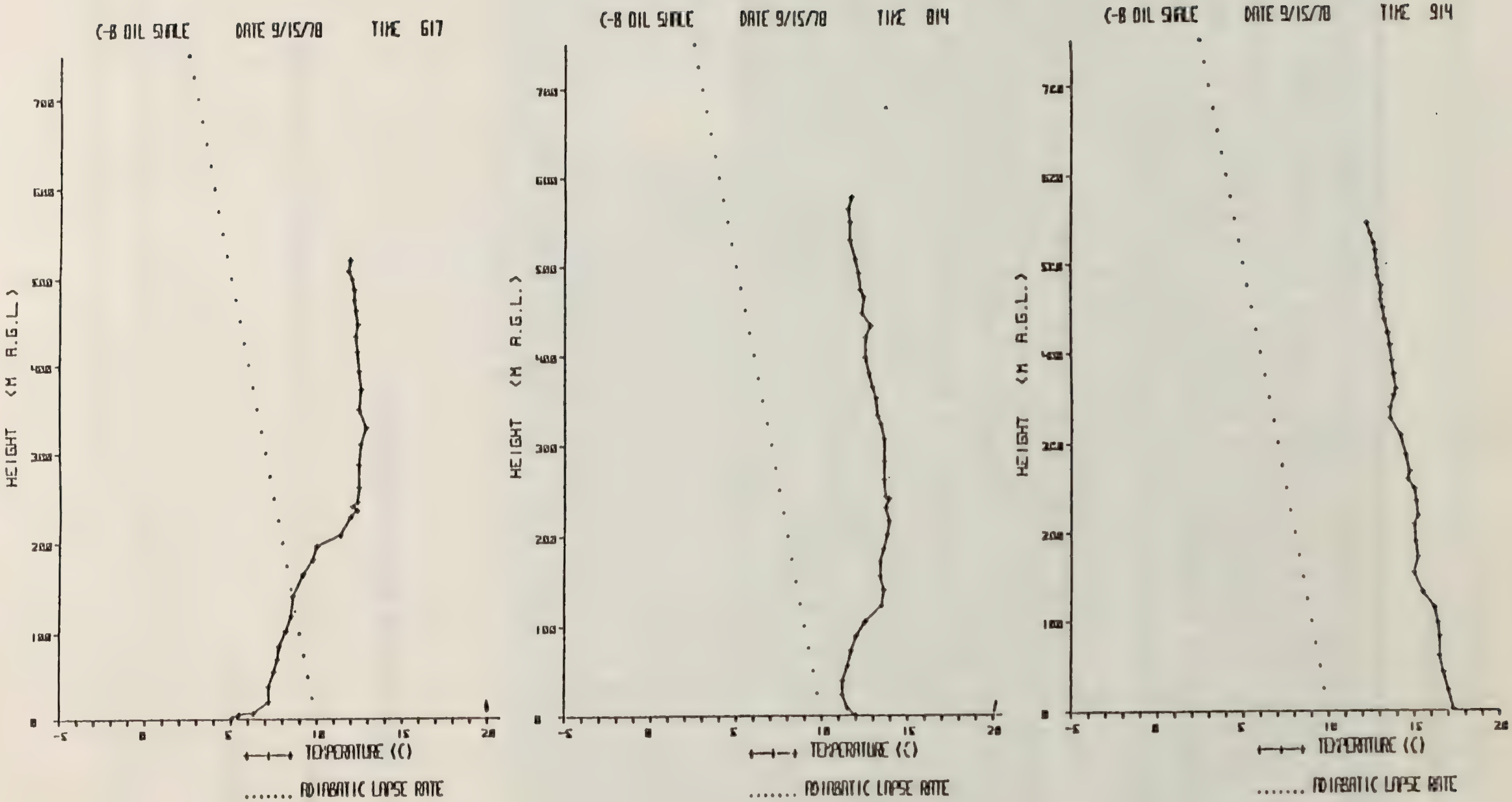

FIGURE 3-11. Temperature soundings taken on 15 September 1978.

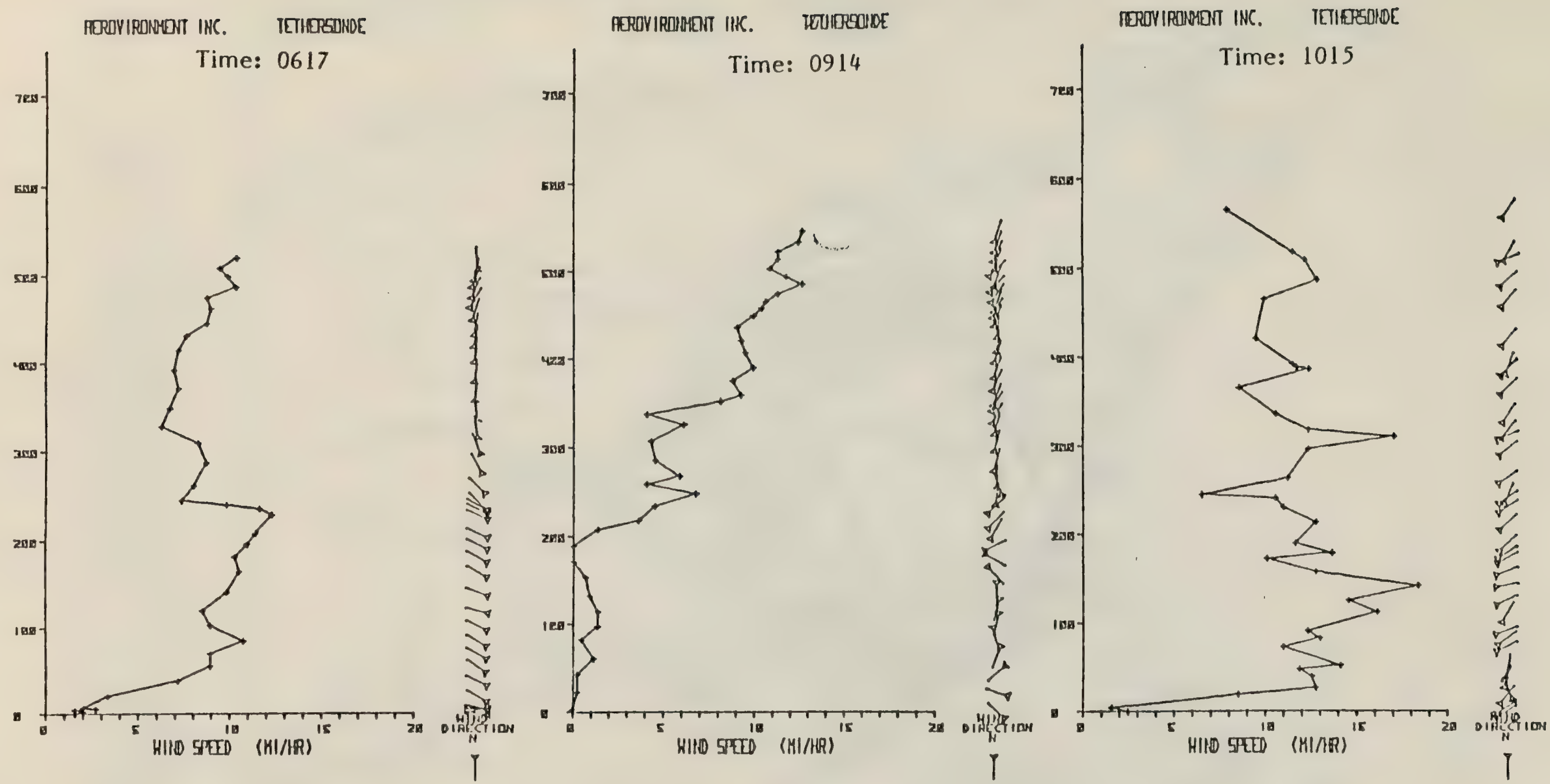

FIGURE 3-12. Wind soundings taken on 15 September 1978.

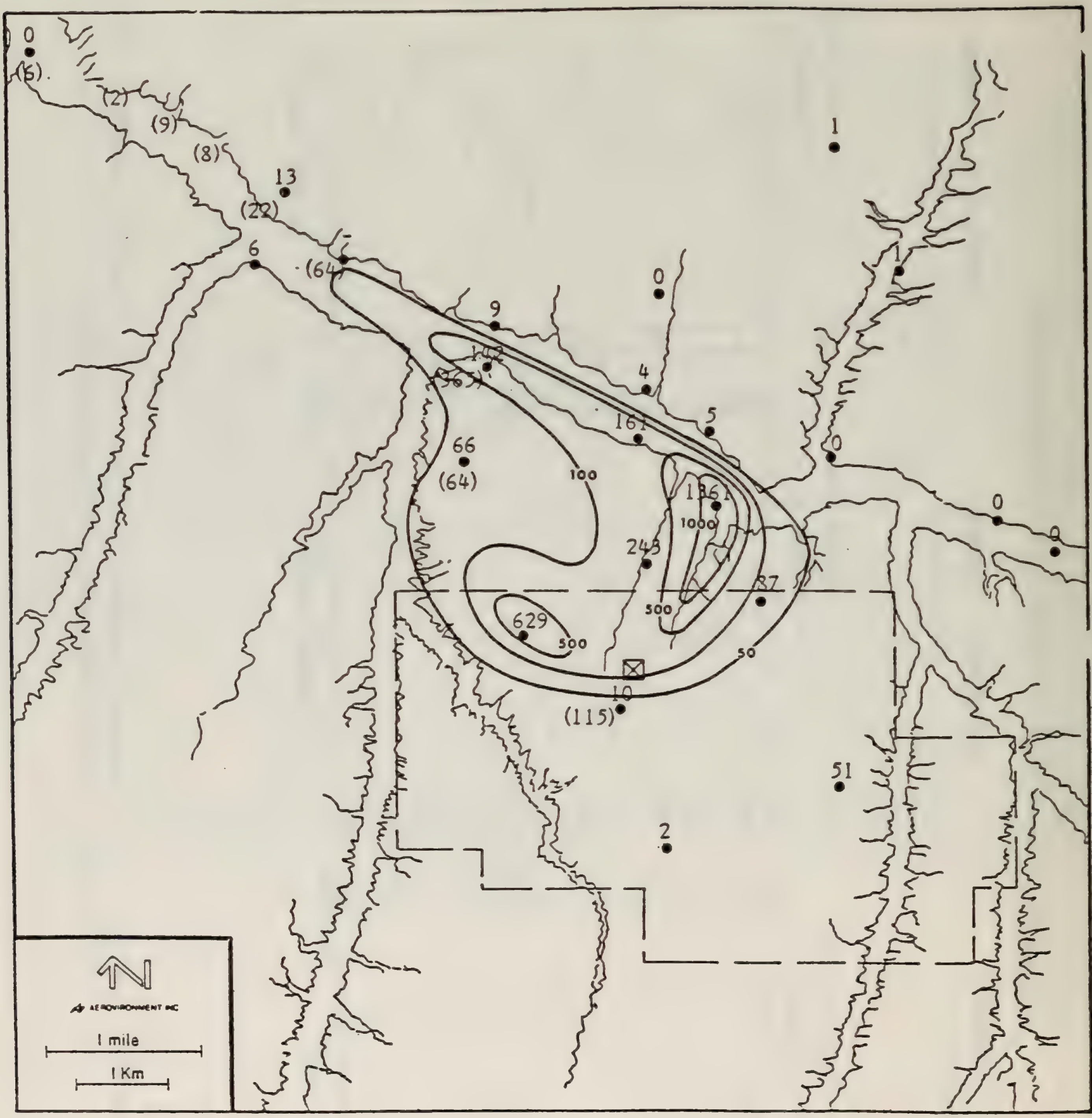

FIGURE 3-13. Isopleths of SF_6 concentration for hour beginning 0600-0700 MDT on 14 September 1978. Numbers without brackets denote one-hour averaged SF_6 concentrations (ppt), while numbers with brackets denote instantaneous SF_6 concentrations (ppt).

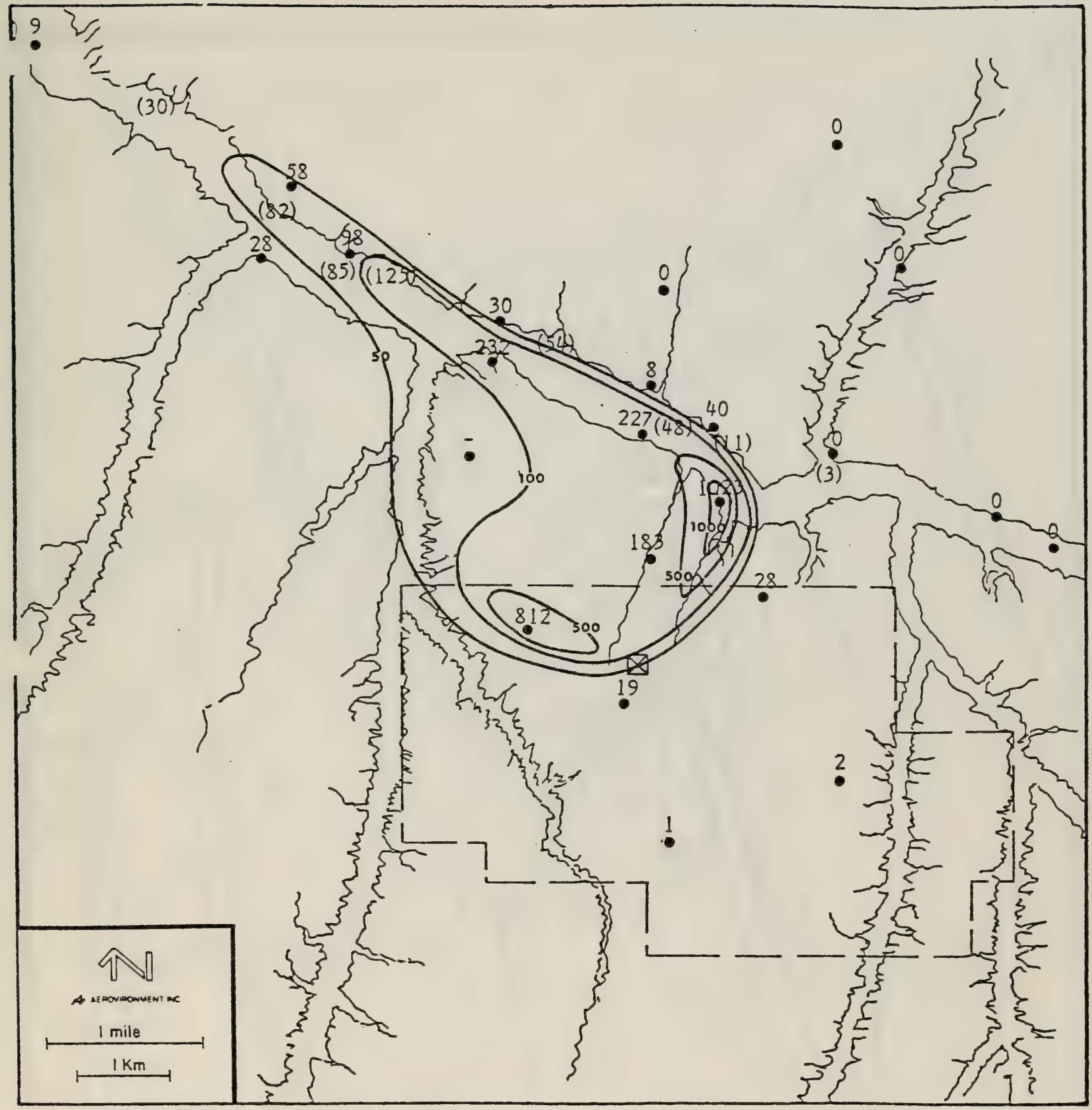

FIGURE 3-14. Isopleths of SF_6 concentration for hour 0700-0800 MDT on 14 September 1978. Numbers without brackets denote one-hour averaged SF_6 concentrations (ppt), while numbers with brackets denote instantaneous SF_6 concentrations (ppt).

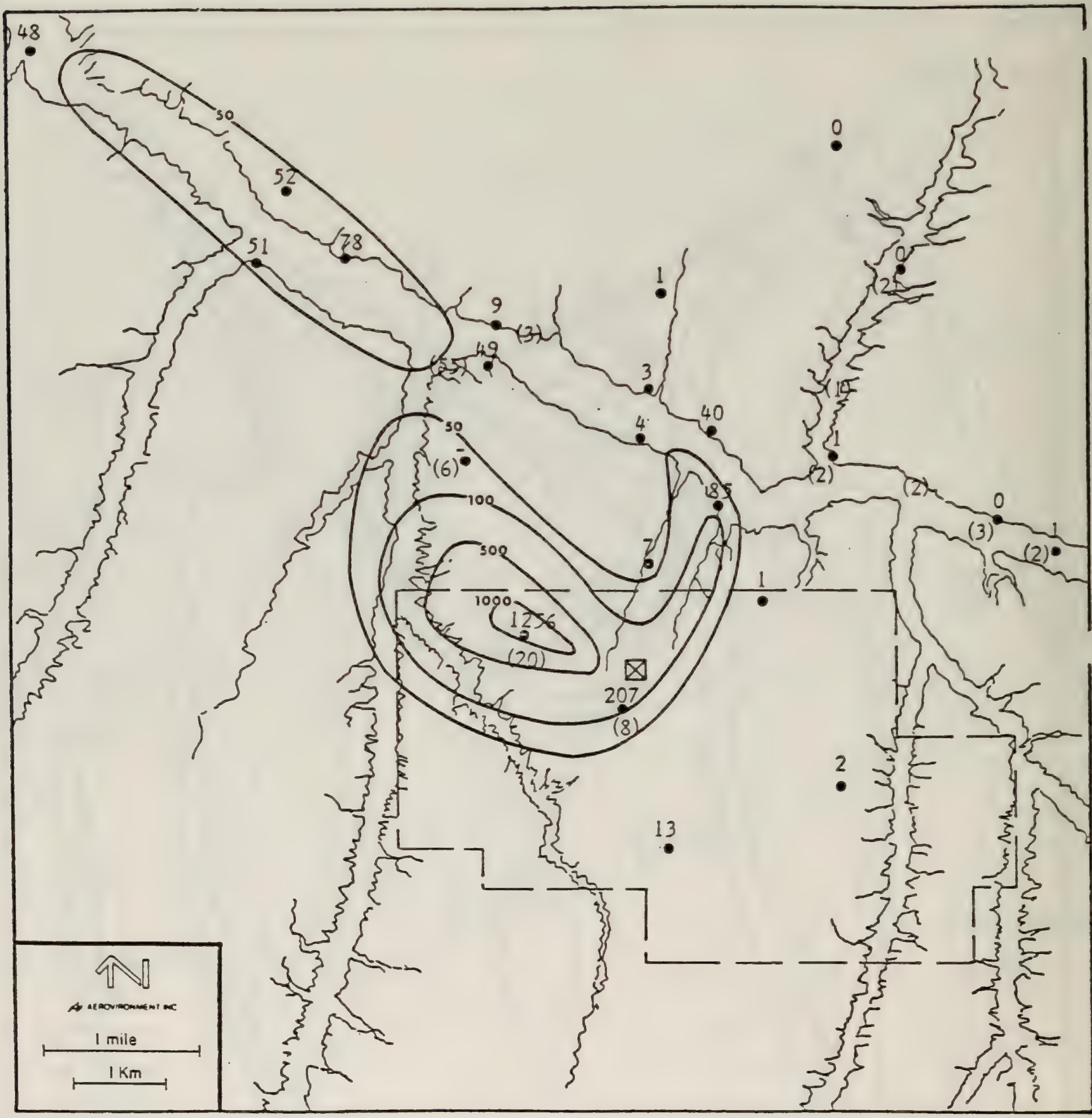

FIGURE 3-15. Isopleths of SF_6 concentration for hour 0800-0900 MDT on 14 September 1978. Numbers without brackets denote one-hour averaged SF_6 concentrations (ppt), while numbers with brackets denote instantaneous SF_6 concentrations (ppt).

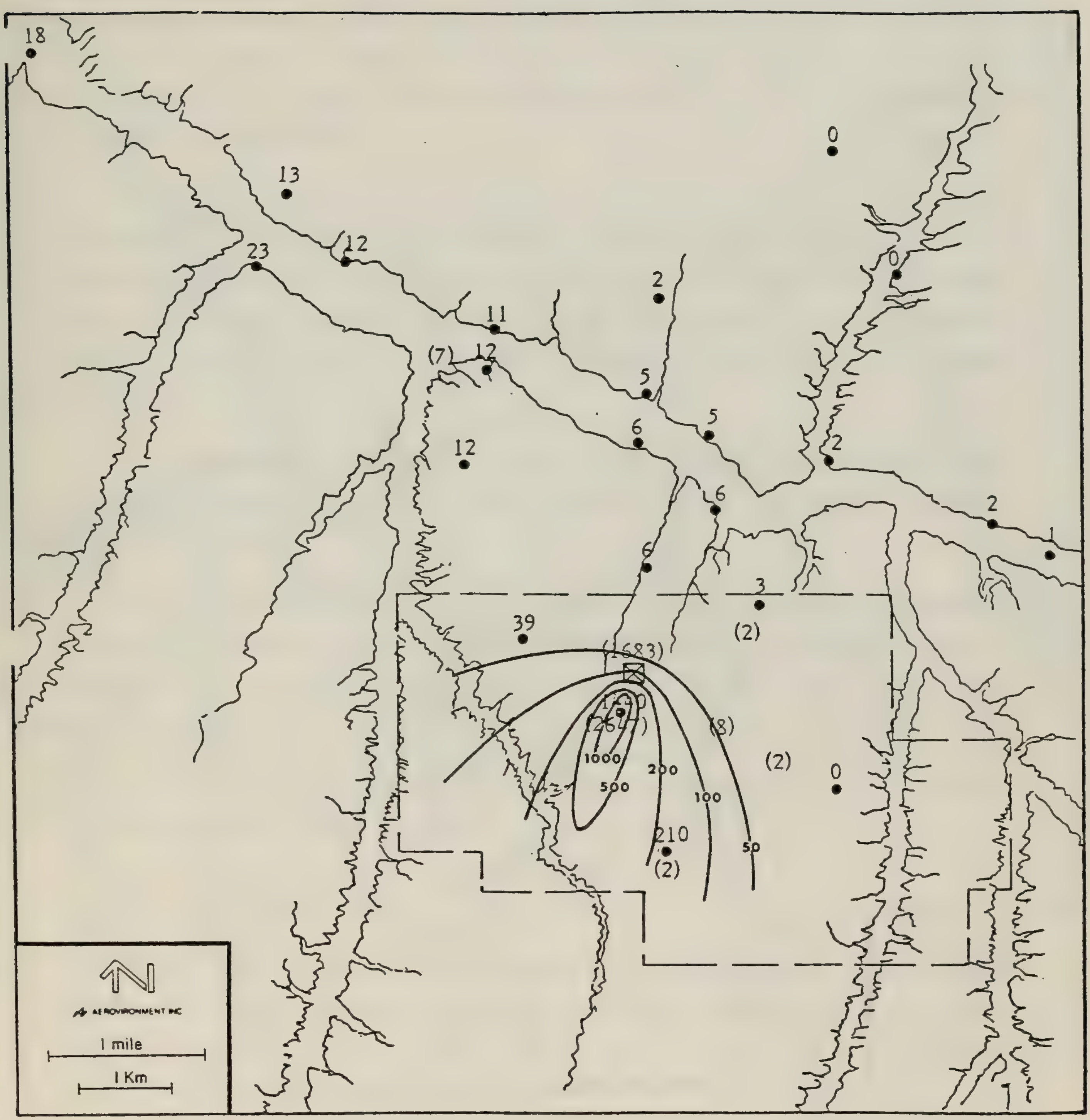

FIGURE 3-16. Isopleths of SF_6 concentration for hour 0900-1000 MDT on 14 September 1978. Numbers without brackets denote one-hour averaged SF_6 concentrations (ppt), while numbers with brackets denote instantaneous SF_6 concentrations (ppt).

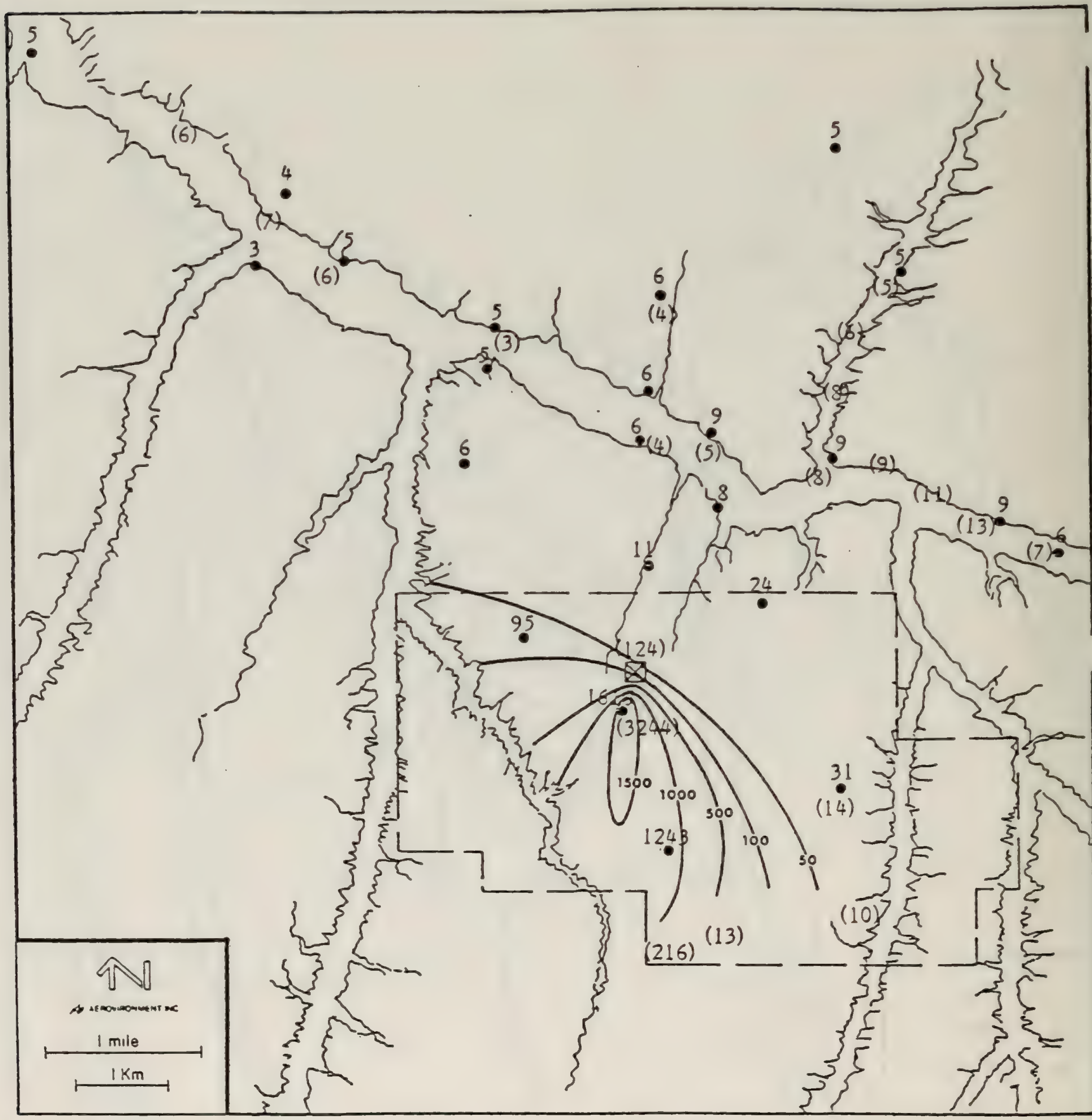

FIGURE 3-17. Isopleths of SF_6 concentration for hour 1000-1100 MDT on 14 September 1978. Numbers without brackets denote one-hour averaged SF_6 concentrations (ppt), while numbers with brackets denote instantaneous SF_6 concentrations (ppt).

drawing the isopleths a bit difficult. Other configurations of isopleths can definitely be derived based on the data. Thus, these figures represent only the authors' conception of the SF_6 distribution. Although the configuration of such isopleths may vary, the concentrations at the receptors were observations and thus any other configuration must conform to such observations.

In the first hour, high concentrations of SF_6 were detected at the mouth of Cottonwood Gulch. SF_6 was also detected along the Piceance Creek east of the mouth of Cottonwood Gulch. This is definitely due to the influence of the drainage wind system. Concentrations were higher on the southern bank of Piceance Creek than on the northern bank. Air flowing down the northern slope of the creek kept the SF_6 from building up on the northern bank.

A similar pattern was observed in the second hour (0700-0800 MDT). In the following hour the tongue flowing down Cottonwood Gulch into Piceance Creek was almost non-existent.

After 0900 MDT, the SF_6 isopleths showed that high concentrations were observed only south of the point of release. Although fumigation of the plume definitely occurred during the hour beginning 0900 MDT, its duration must have been very short and thus did not result in any high concentrations when averaged over an hour. SF_6 was still detected along the creek during the last two hours, not because the plume was over the creek, but because the flow reversal (from drainage to upslope) brought back SF_6 that was earlier transported down the creek.

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Figures 3-18 through 3-22 show isopleths of SF_6 concentrations constructed from observations taken on the second day of the experiment. During the first three hours, only minute amounts of SF_6 were observed at the ground stations. The only location with any measurable quantities to speak of was sampler location #3 to the west-northwest of the release site. Based on the SF_6 distribution in the last two hours of the experiment (will be discussed shortly) as well as the fact that only a shallow surface-based inversion was observed from the sounding, it was possible that the SF_6 was lofting above the

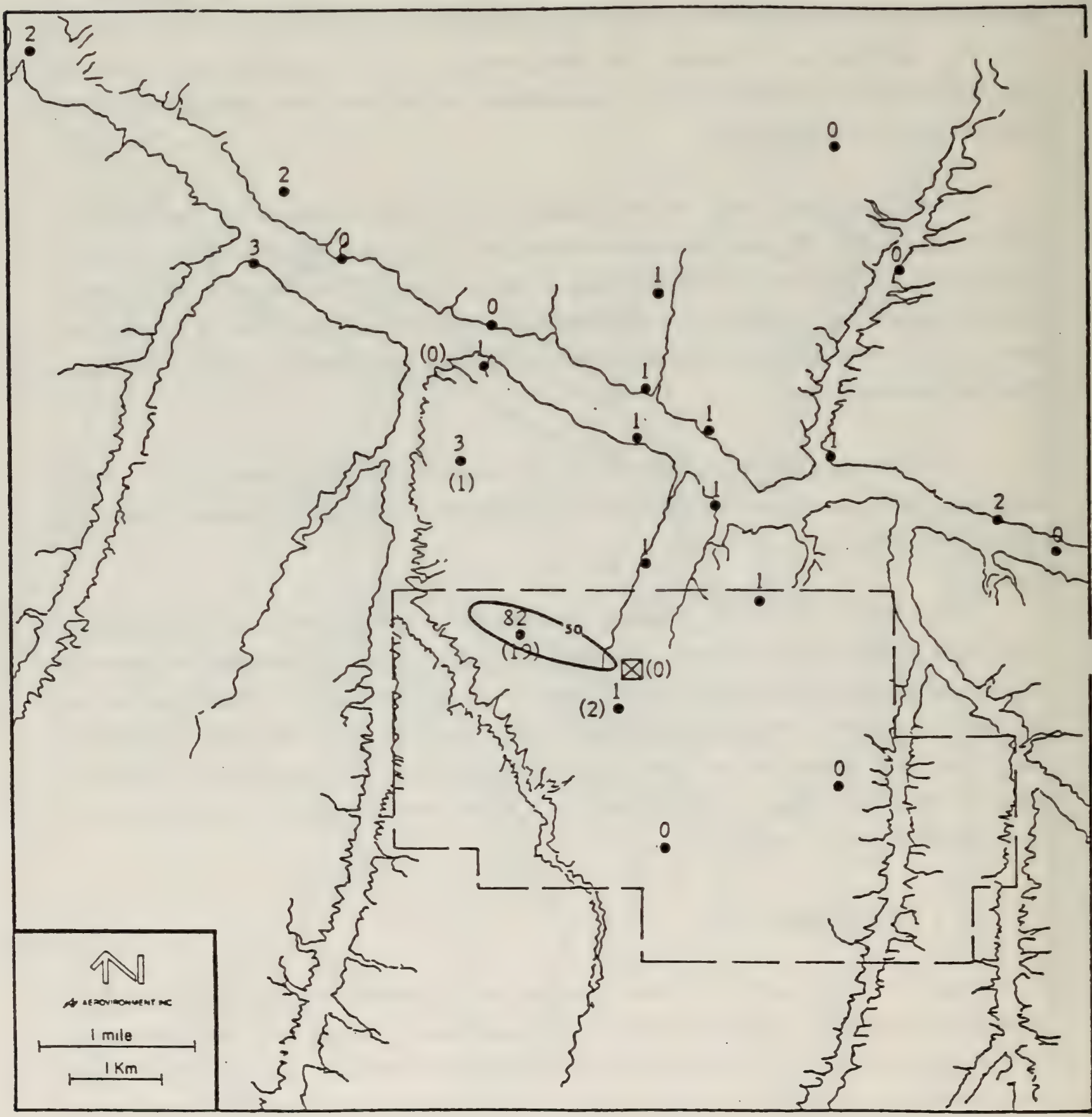

FIGURE 3-18. Isopleths of SF_6 concentration for hour beginning 0600-0700 MDT on 15 September 1978. Numbers without brackets denote one-hour averaged SF_6 concentrations (ppt), while numbers with brackets denote instantaneous SF_6 concentrations (ppt).

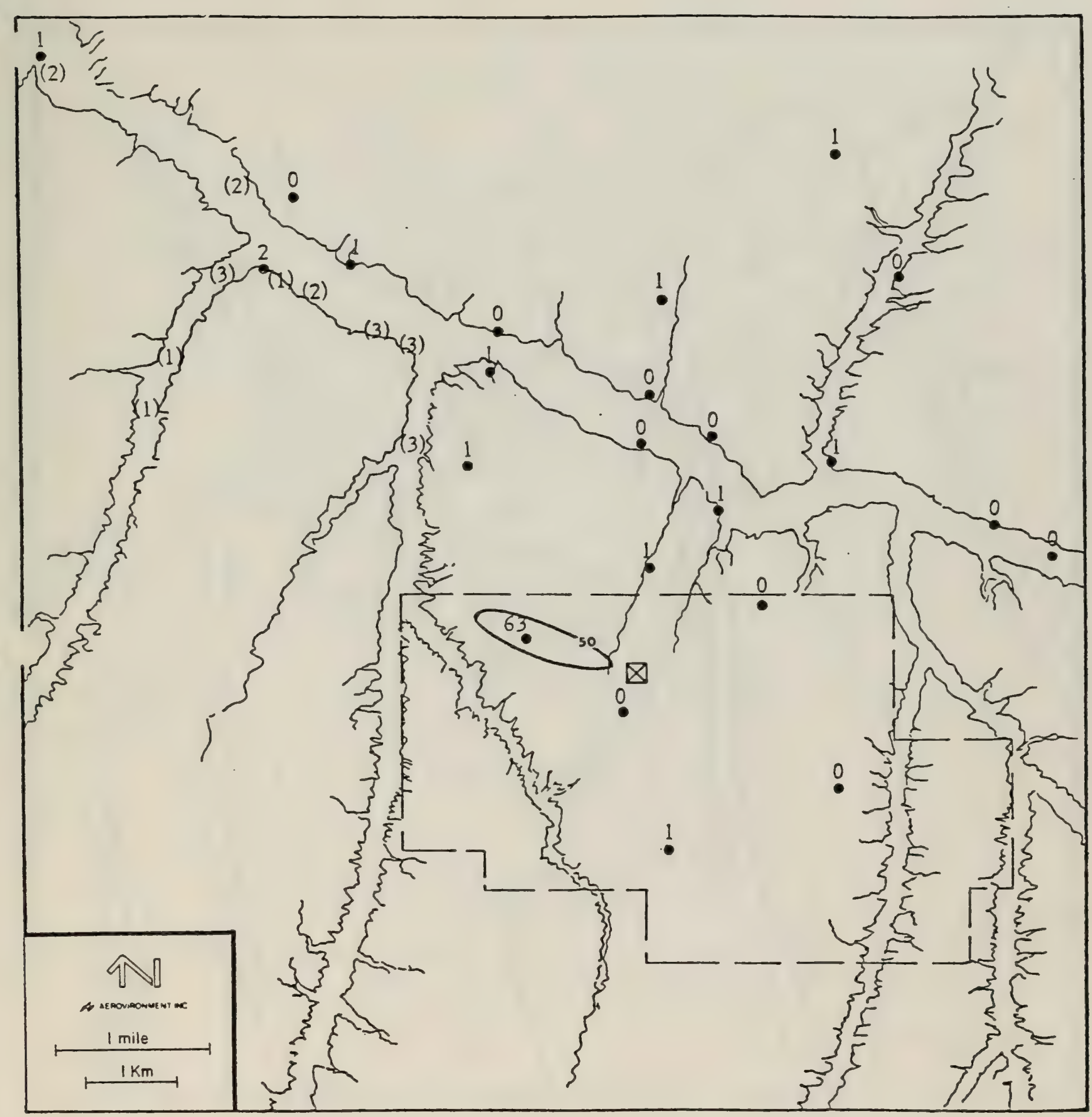

FIGURE 3-19. Isopleths of SF_6 concentration for hour 0700-0800 MDT on 15 September 1978. Numbers without brackets denote one-hour averaged SF_6 concentrations (ppt), while numbers with brackets denote instantaneous SF_6 concentrations (ppt).

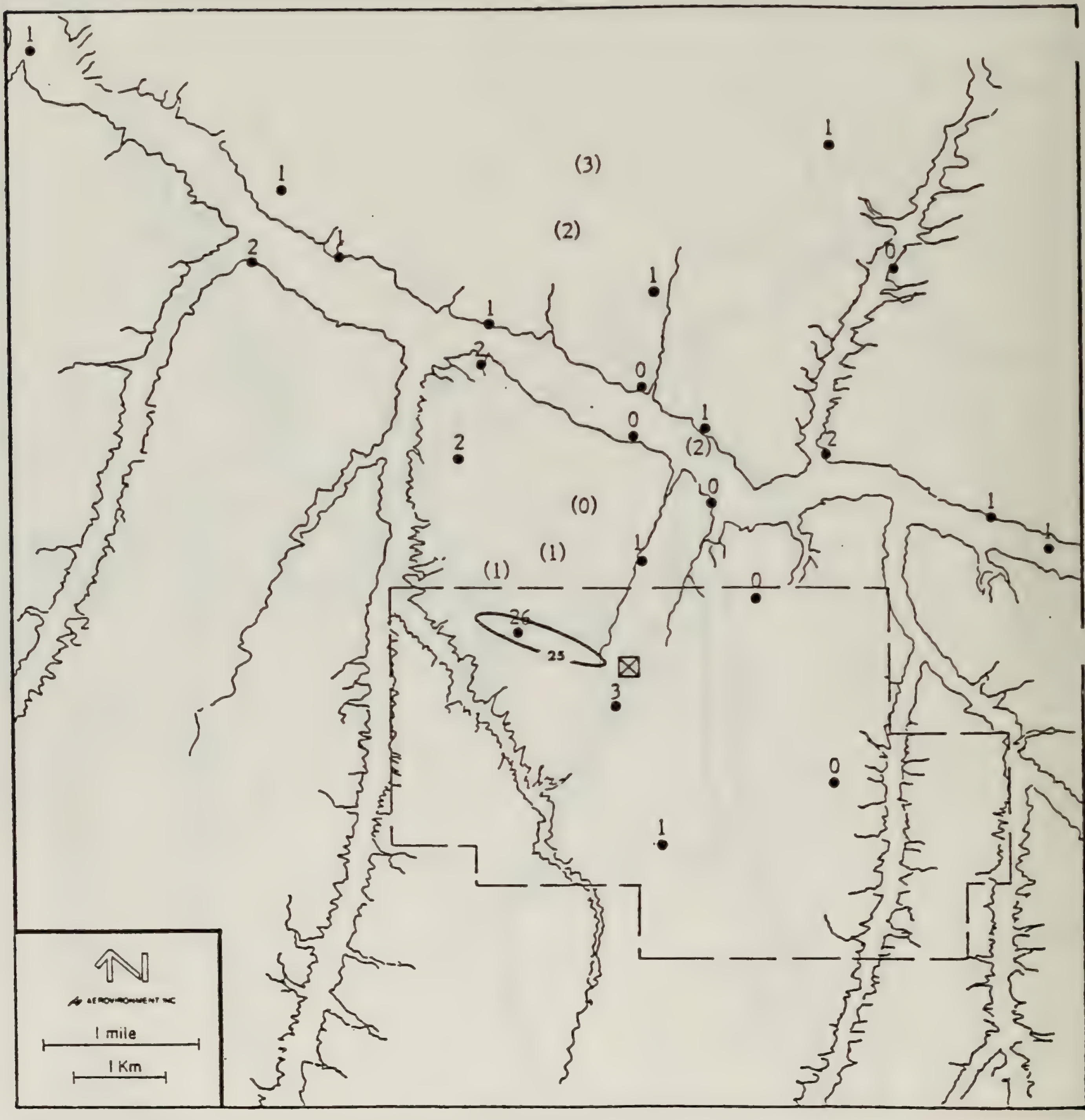

FIGURE 3-20. Isopleths of SF_6 concentration for hour 0800-0900 MDT on 15 September 1978. Numbers without brackets denote one-hour averaged SF_6 concentrations (ppt), while numbers with brackets denote instantaneous SF_6 concentrations (ppt).

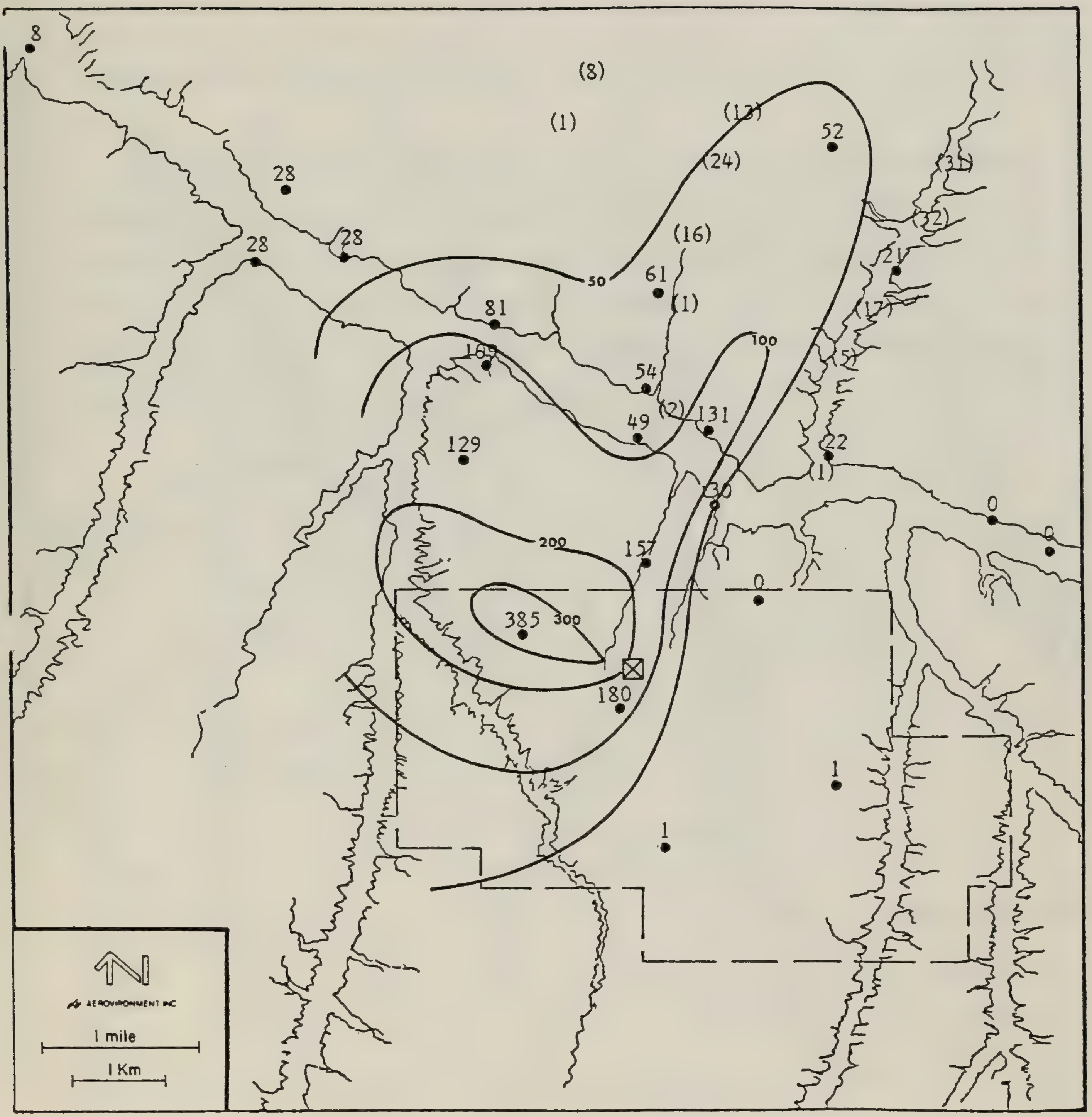

FIGURE 3-21. Isopleths of SF_6 concentration for hour 0900-1000 MDT on 15 September 1978. Numbers without brackets denote one-hour averaged SF_6 concentrations (ppt), while numbers with brackets denote instantaneous SF_6 concentrations (ppt).

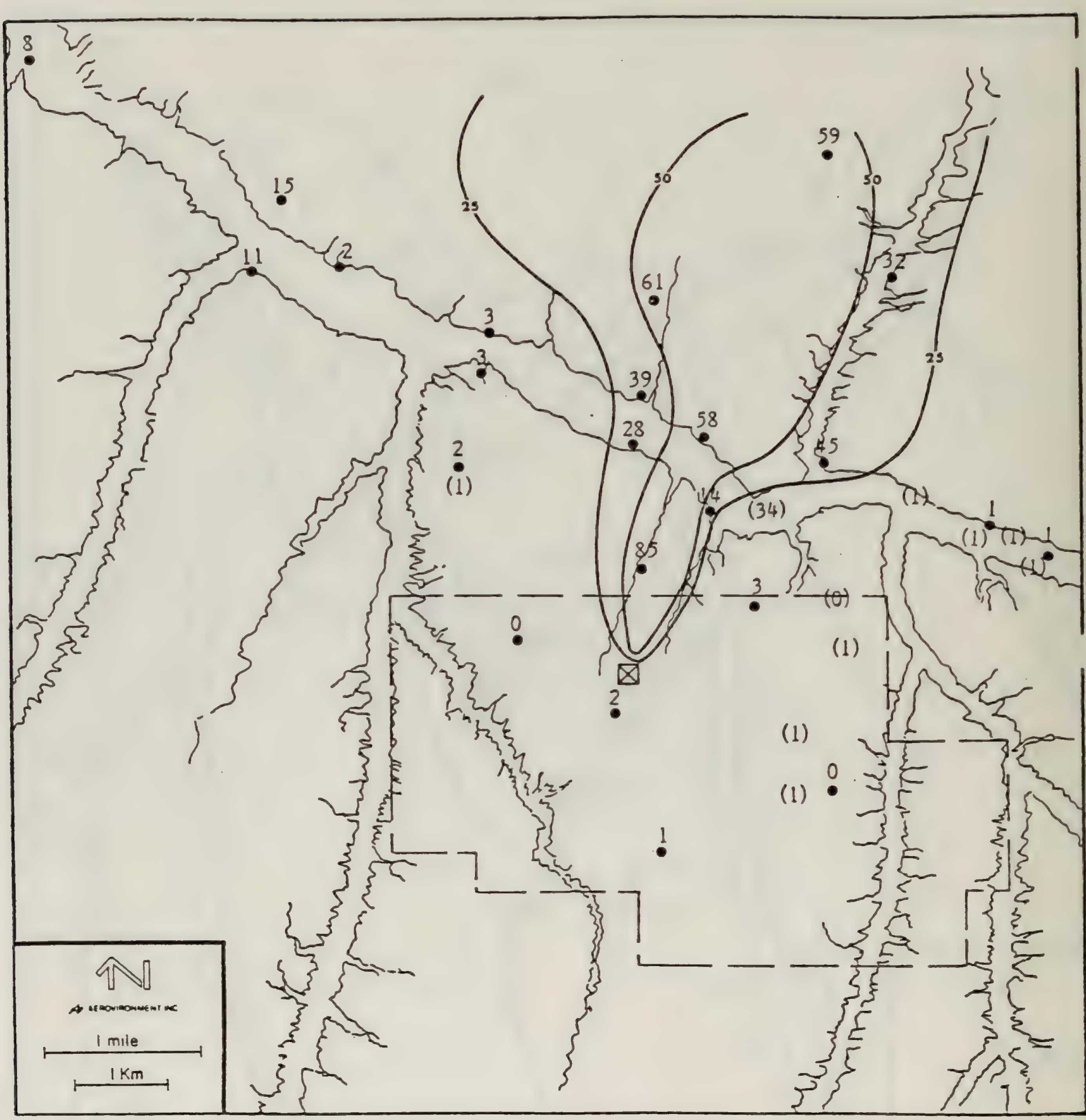

FIGURE 3-22. Isopleths of SF_6 concentration for hour 1000-1100 MDT on 15 September 1978. Numbers without brackets denote one-hour averaged SF_6 concentrations (ppt), while numbers with brackets denote instantaneous SF_6 concentrations (ppt).

surface-based inversion. As the wind was still generally from the east, it was also possible that whatever minute amounts that got into the surface layer were transported to the west with some finding their way down to the Piceance Creek.

The last two hours of SF_6 distribution showed that the SF_6 plume was responding to the synoptic wind flow. High concentrations were observed north and west of the point of release, down the creek and up along the south-facing slope across the creek in the hour beginning 0900 MDT. The SF_6 distribution during this hour was a little bit more complicated than the one in 1000-1100 MDT, because of the transition from weak drainage to synoptic flow. The distribution for the last hour was quite straightforward. It showed that the plume was traveling down the creek and up the slope on the other side, following the synoptic wind which was out of the south-southwest.

4. OBSERVATIONS

A number of observations can be deduced from the results of the experiment.

(1) On 14 September, when the synoptic pressure gradients were weak, local meteorology was responsible for the transport and diffusion of pollutants during nighttime and early morning hours. Under such a situation, the synoptic wind flow was not able to establish itself until after mid-day.

(2) When the plume was released within a layer of very stable air in complex terrain, the plume followed constant potential temperature surfaces, which followed the contour of the ground. It did not just fan out and stay at the same elevation above sea level. In specific, the plume flowed into Piceance Creek and followed the creek downstream rather than traveling across the creek at the level of release and impinging on the surface of the south-facing slope north of Piceance Creek. Contrary to observations of a fanning plume on flat terrain, a fanning plume over tract C-b did get down to the ground surface due to turbulence associated with the shearing effect of the drainage wind.

(3) Fumigation of the plume did not result in high concentrations when measurements were averaged over a period of one-hour or more.

(4) On 15 September, when the surface-based inversion was shallow, the plume lofted above the inversion and pollutant concentrations at the surface were miniscule.

(5) When the plume was released in a neutral-lapsed layer, the plume centerline followed the contour of ground surface as it traveled downwind.

5. REFERENCES

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C-b Shale Oil Venture (1977): U.S. Department of the Interior prototype oil shale leasing program, oil shale tract C-b, environmental baseline program final report (November 1974 through October 1976). Volume III, Meteorology, Air Quality, and Noise.

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Chan, M.W. (1978): The C-b shale oil venture tracer study progress report No. 1, AeroVironment Inc., Pasadena, California.

Morris, A.L. (1977): Synthesizing mining data at the C-b oil shale tract. Ambient Analysis, Inc., Boulder, Colorado.

APPENDIX A

Meteorological Data

TABLE A-1. Meteorological data, 14 September 1978.

		Time (MDT)						
Site	Parameter	0400-0500	0500-0600	0600-0700	0700-0800	0800-0900	0900-1000	1000-1100
20	W10	110/4.0	105/4.0	105/4.0	105/3.0	320/5.0	295/6.0	300/7.0
22	W10	100/7.5	080/5.0	090/5.5	100/6.5	100/7.5	095/6.5	295/7.5
	T10	-1.4	-2.4	-2.5	-2.4	2.0	8.1	14.3
23	W10	VAR/2.0	205/2.5	300/2.0	120/2.0	VAR/1.5	045/2.0	360/2.0
	W30	VAR/1.0	VAR/1.0	300/1.5	220/2.0	090/1.0	090/2.5	030/4.0
	W60	015/.5	215/.5	300/1.5	220/.5	035/.5	095/2.5	025/4.0
	T10	7.2	7.5	5.5	5.2	6.2	9.1	12.3
	T60	8.5	8.5	7.0	7.0	7.5	9.5	12.0
	ΔT	1.3	1.0	1.5	1.8	1.3	0.4	-0.3
	σ_w (m/sec)	.03	.03	.02	.02	.04	.04	.02
	σ_θ (deg.)	6	9	6	7	19	26	22
24	W10	290/IM	VAR/IM	VAR/IM	050/IM	330/IM	300/IM	195/IM
	T10	1.4	1.5	3.1	8.4	3.6	16.3	19.2
42	W10	055/3.0	070/2.5	065/2.5	040/2.0	340/3.0	280/5.0	220/11.0
	T10	-1.8	-2.5	-2.4	2.9	9.2	12.6	16.8
45	W10	345/.5	325/.5	335/.5	130/1.0	115/.5	145/3.0	150/4.0
	T10	-1.3	-1.6	-2.2	-0.4	4.6	10.1	13.9
46	W10	115/2.0	115/2.5	120/3.0	140/2.5	260/2.5	280/2.0	030/2.0
	T10	-1.3	-1.7	-1.1	4.6	10.7	16.4	21.5
56	W10	160/4.5	135/3.0	140/3.0	095/2.0	210/7.0	310/9.5	255/8.5
	T10	-5.3	-6.2	-4.2	1.5	6.2	9.8	14.9

Note: All temperatures in ^{o}C, wind directions in degrees, wind speeds in miles per hour, VAR means variable direction, and IM means instrument malfunction.

TABLE A-2. Meteorological data, 15 September 1978.

		Time (MDT)						
Site	Parameter	0400-0500	0500-0600	0600-0700	0700-0800	0800-0900	0900-1000	1000-1100
20	W10	140/5.0	140/5.0	100/4.0	130/4.0	110/2.0	190/8.0	220/8.0
22	W10	050/3.0	070/4.0	105/8.0	110/7.5	075/4.0	100/4.5	055/4.0
	T10	5.0	4.1	4.0	4.1	3.2	5.9	11.4
23	W10	100/5.0	110/4.0	180/3.5	125/2.0	225/7.5	210/14.5	210/IM
	W30	110/5.5	125/3.5	190/5.0	180/3.0	230/6.5	225/13.0	230/14.0
	W60	120/4.0	155/4.0	175/8.5	180/3.0	230/6.0	220/12.5	220/14.0
	T10	5.8	7.2	5.6	12.6	14.4	15.0	16.9
	T60	9.5	9.5	10.0	11.5	13.5	14.0	15.5
	ΔT	3.7	2.3	4.4	0.9	-0.9	-1.0	-1.4
	σ_w (m/sec)	.03	.03	.03	.03	.03	.03	.03
	σ_θ (deg.)	14	15	26	25	26	20	23
24	W10	120/IM	110/IM	090/IM	055/IM	280/IM	205/IM	210/IM
	T10	6.3	5.7	6.2	11.2	15.0	17.5	19.2
42	W10	100/8.0	085/5.5	070/4.0	020/2.5	310/3.5	185/14.0	180/14.0
	T10	4.7	3.8	4.2	7.2	13.4	15.9	17.8
45	W10	005/1.0	340/1.5	355/1.5	020/.5	065/.5	120/3.5	150/10.5
	T10	5.7	4.5	3.9	5.8	10.3	15.7	16.9
46	W10	115/4.0	115/4.0	120/3.5	120/2.5	140/2.5	155/8.5	165/8.5
	T10	6.7	6.0	5.4	9.7	17.3	21.0	22.9
56	W10	125/5.0	125/4.5	120/4.0	070/4.5	090/2.5	180/9.5	180/10.5
	T10	2.1	2.2	2.7	7.6	14.8	18.9	20.7

Note: All temperatures in °C, wind directions in degrees, wind speed in miles per hour, IM means instrument malfunction.

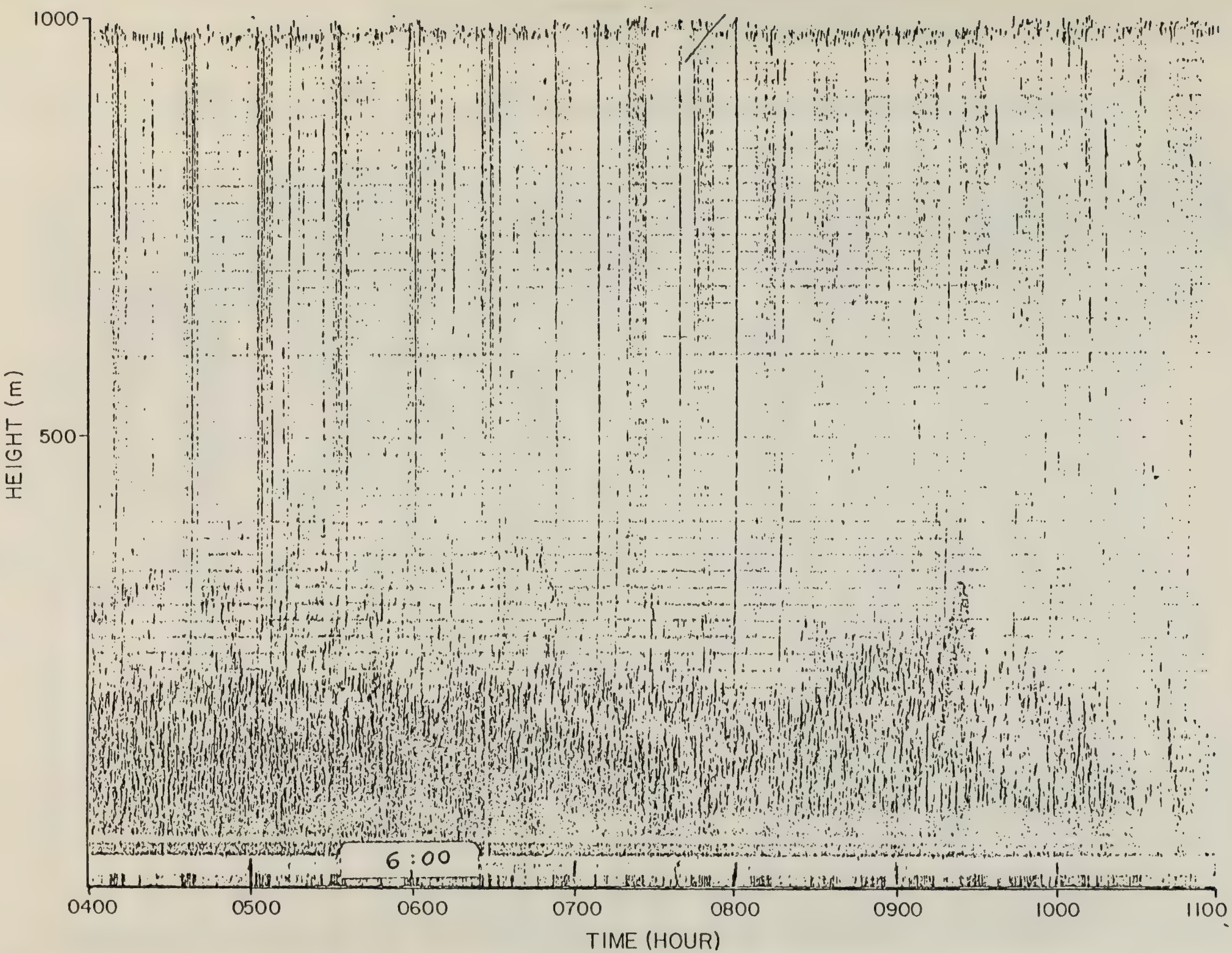


FIGURE A-1. Acoustic radar, 14 September 1978.

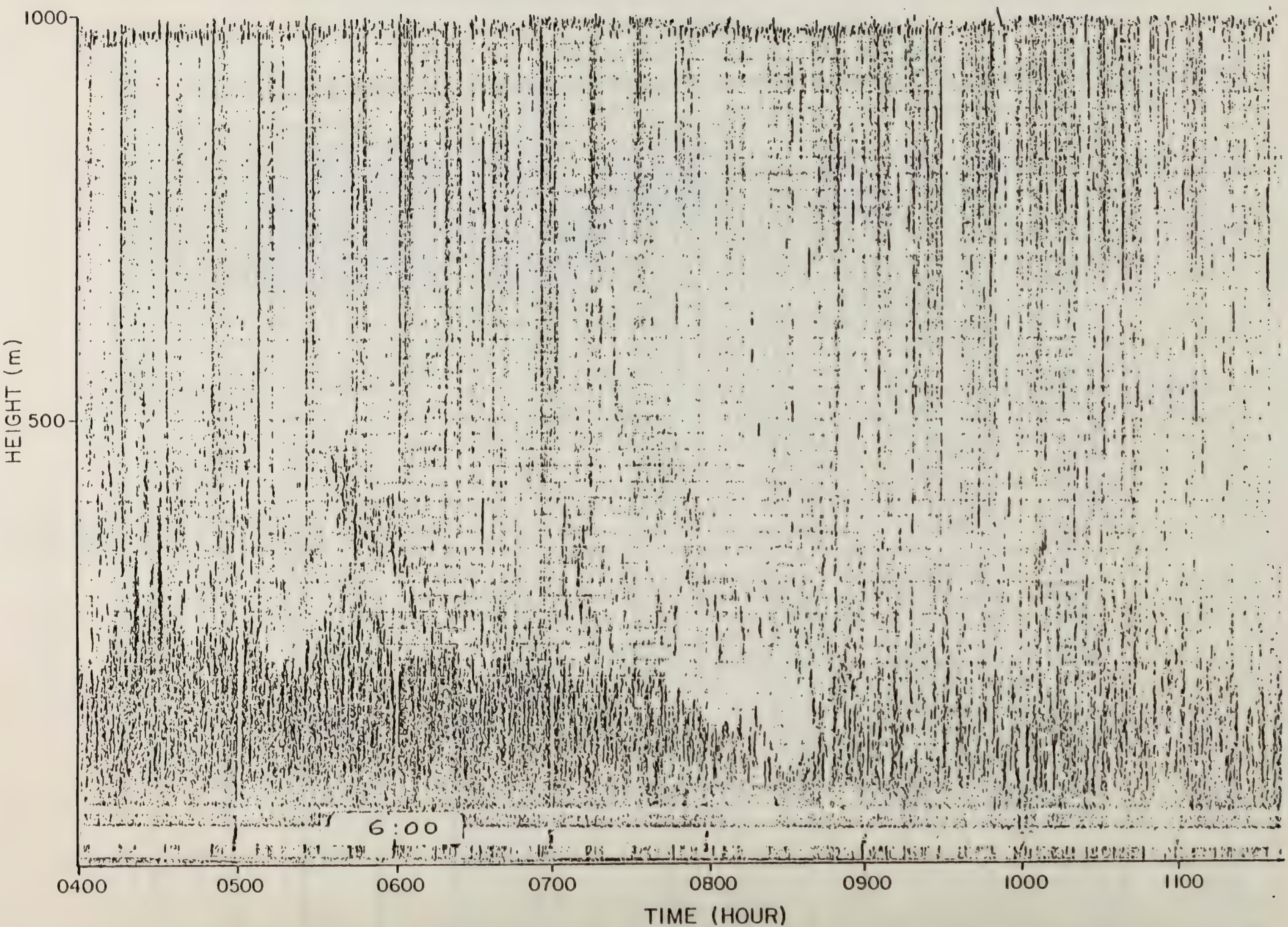
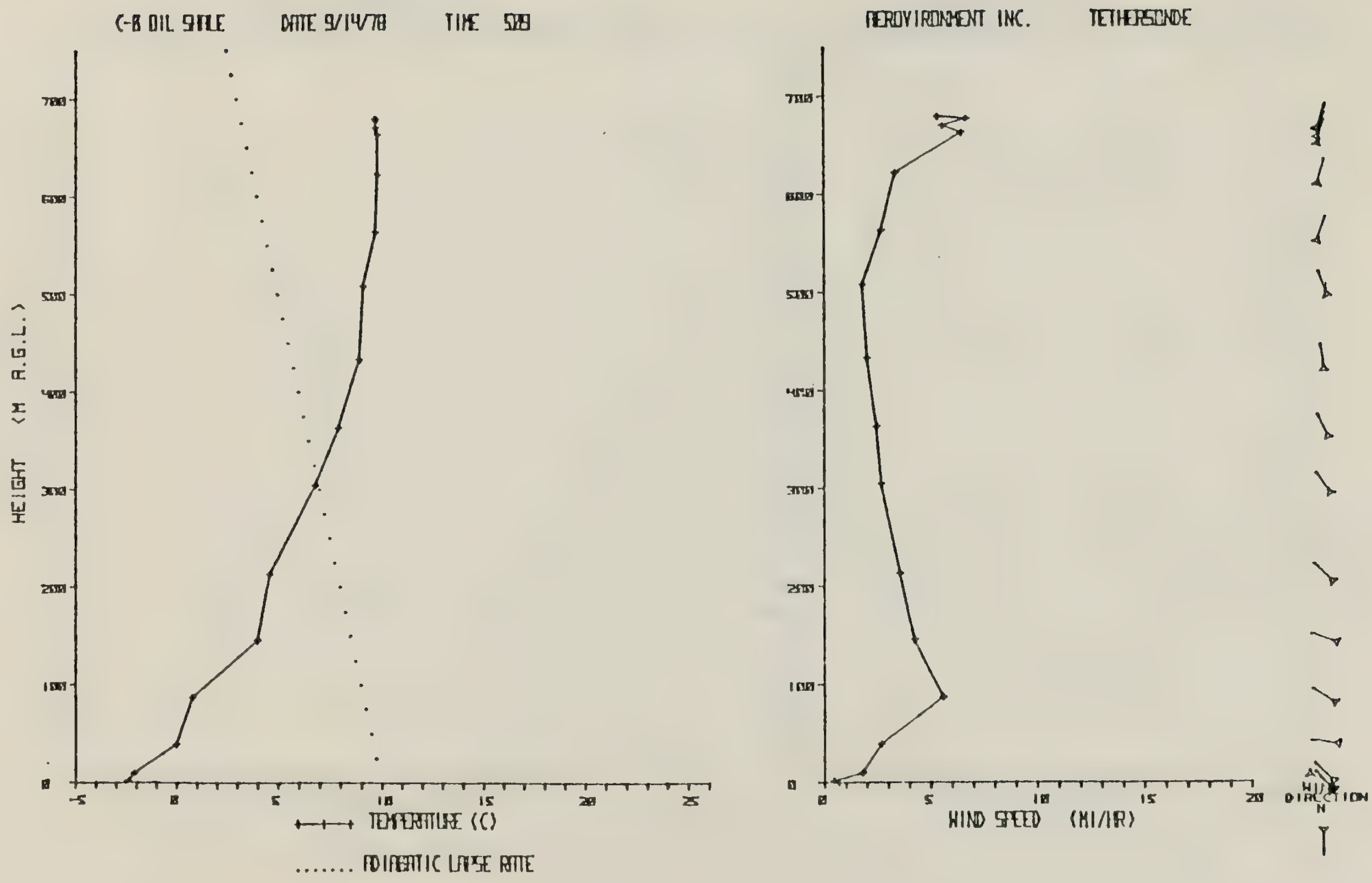
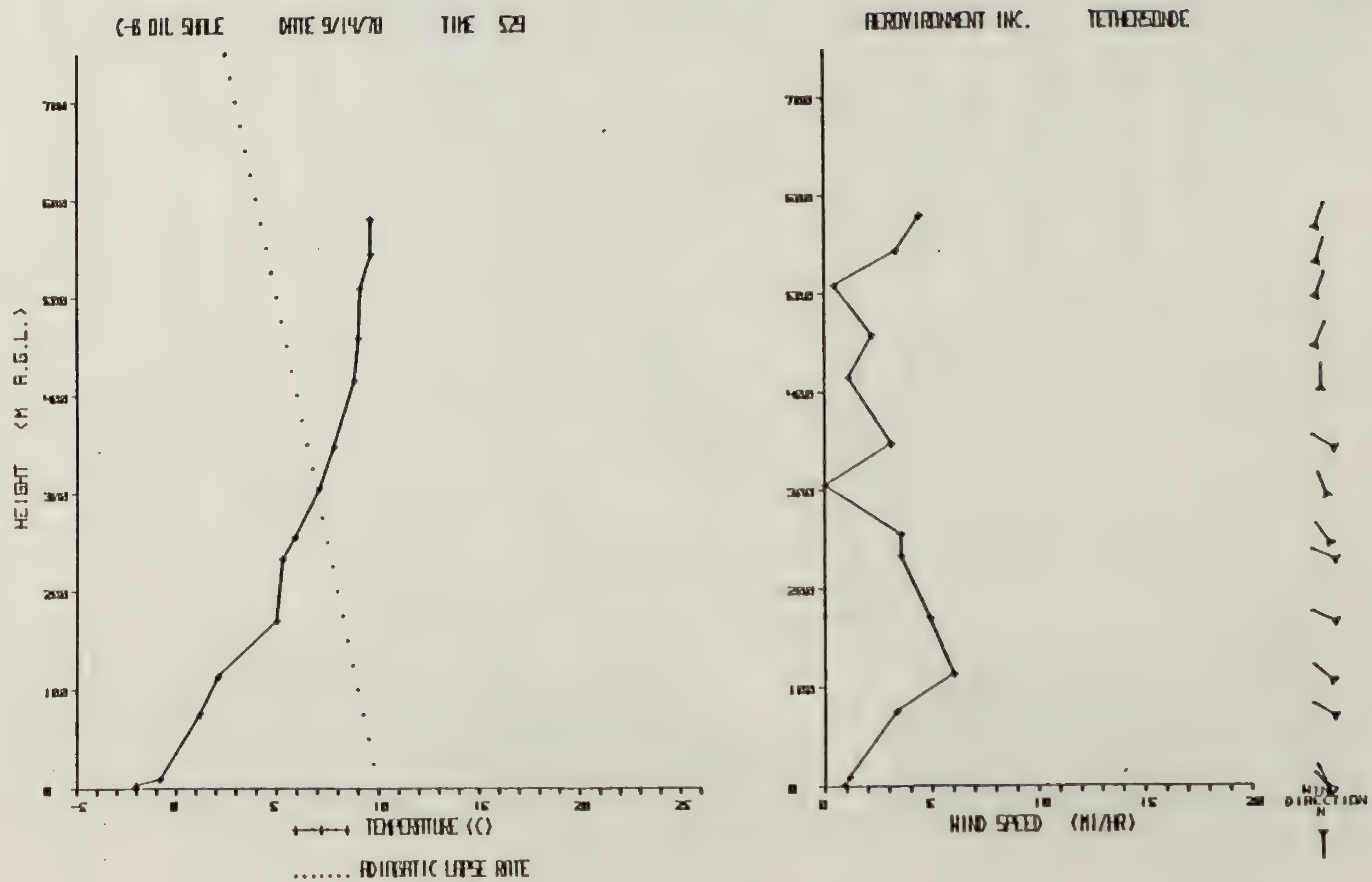


FIGURE A-2. Acoustic dar, 15 September 1978.

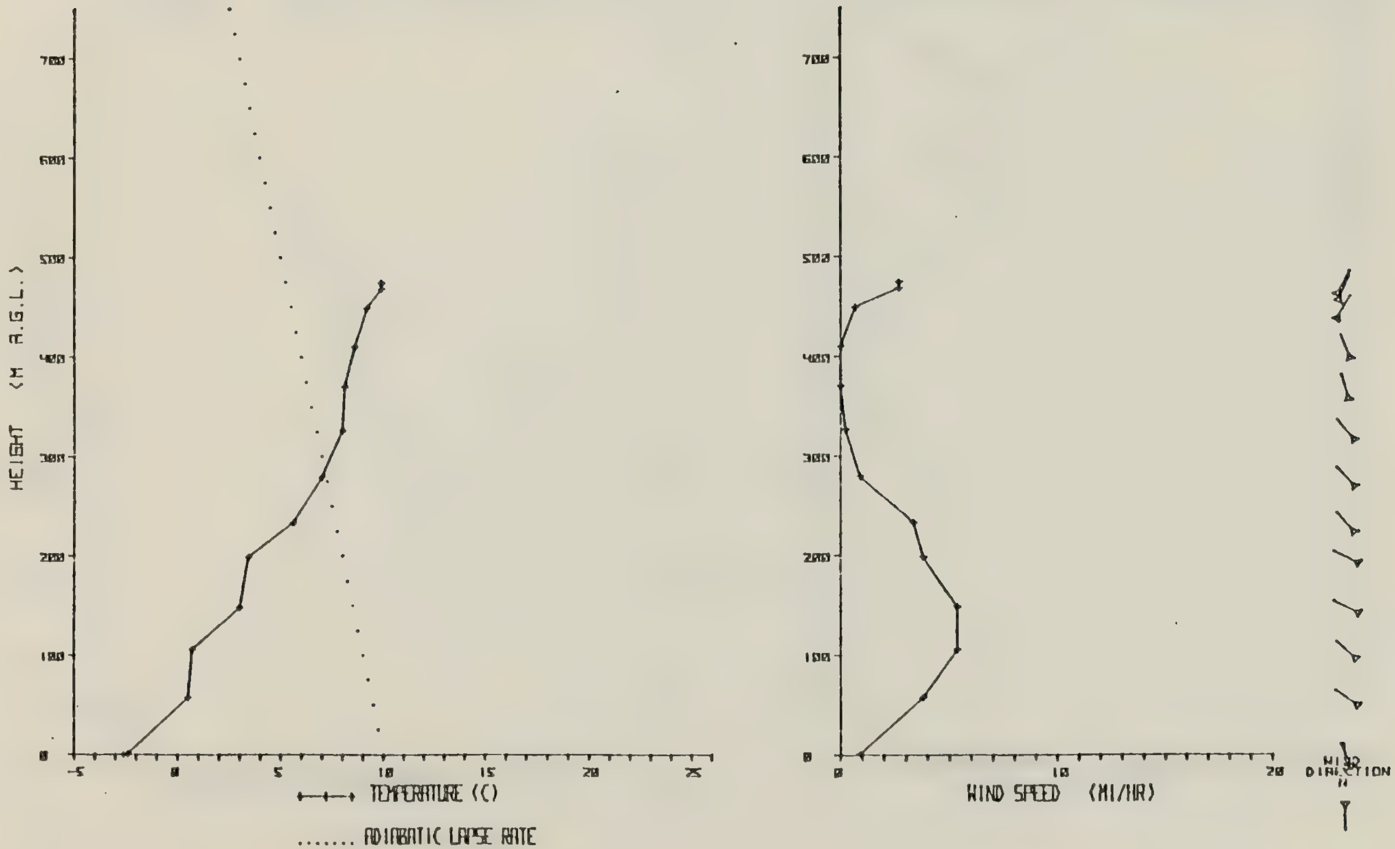

C-B OIL SHALE
DATE 9/14/78
TIME 528
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N

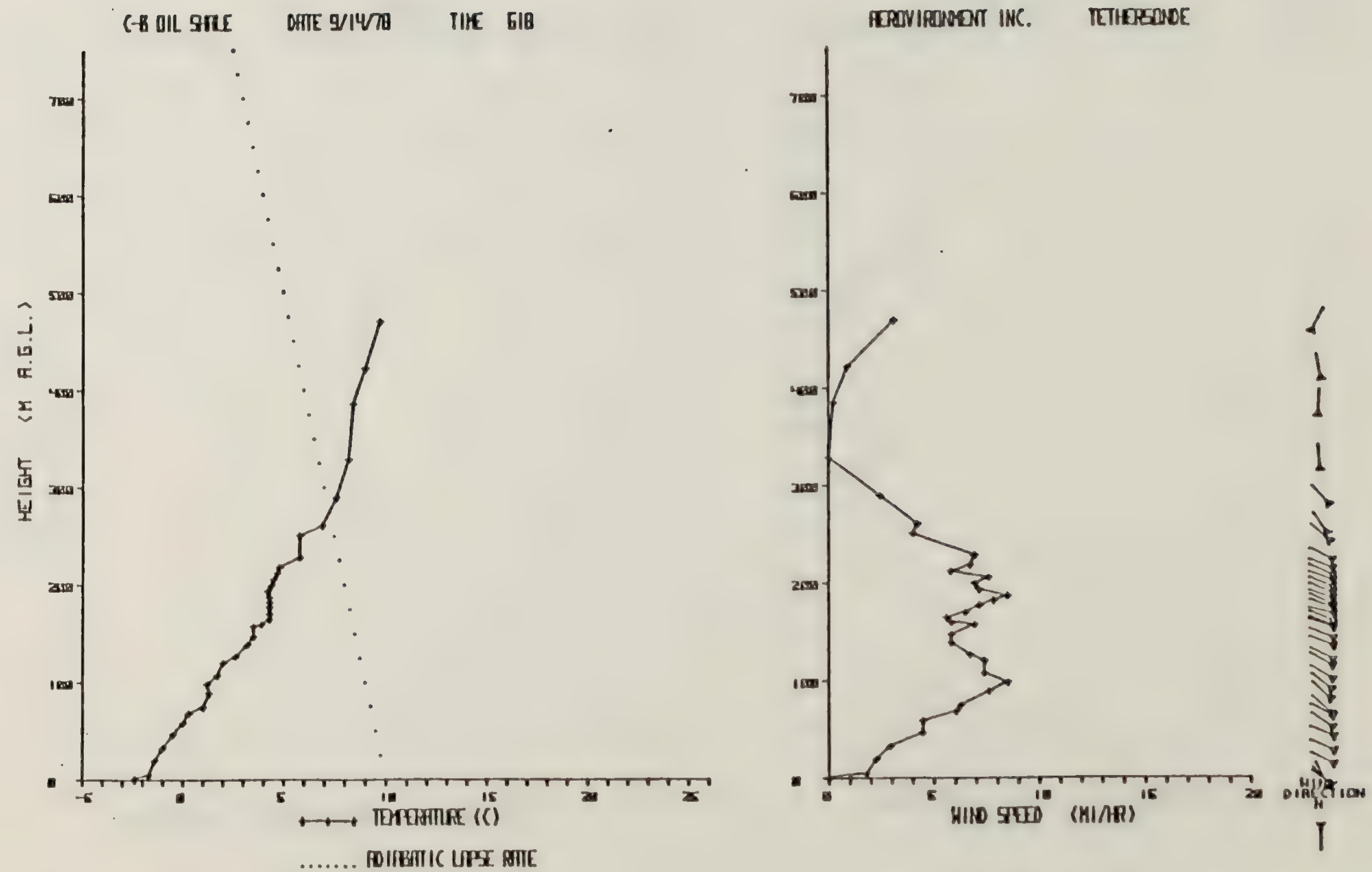


C-B OIL SHALE DATE 9/14/78 TIME 529
AEROVIRONMENT INC. TETHERSONDE
HEIGHT (M A.G.L.)
0
100
200
300
400
500
600
700
-5
0
5
10
15
20
25
TEMPERATURE (C)
ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N

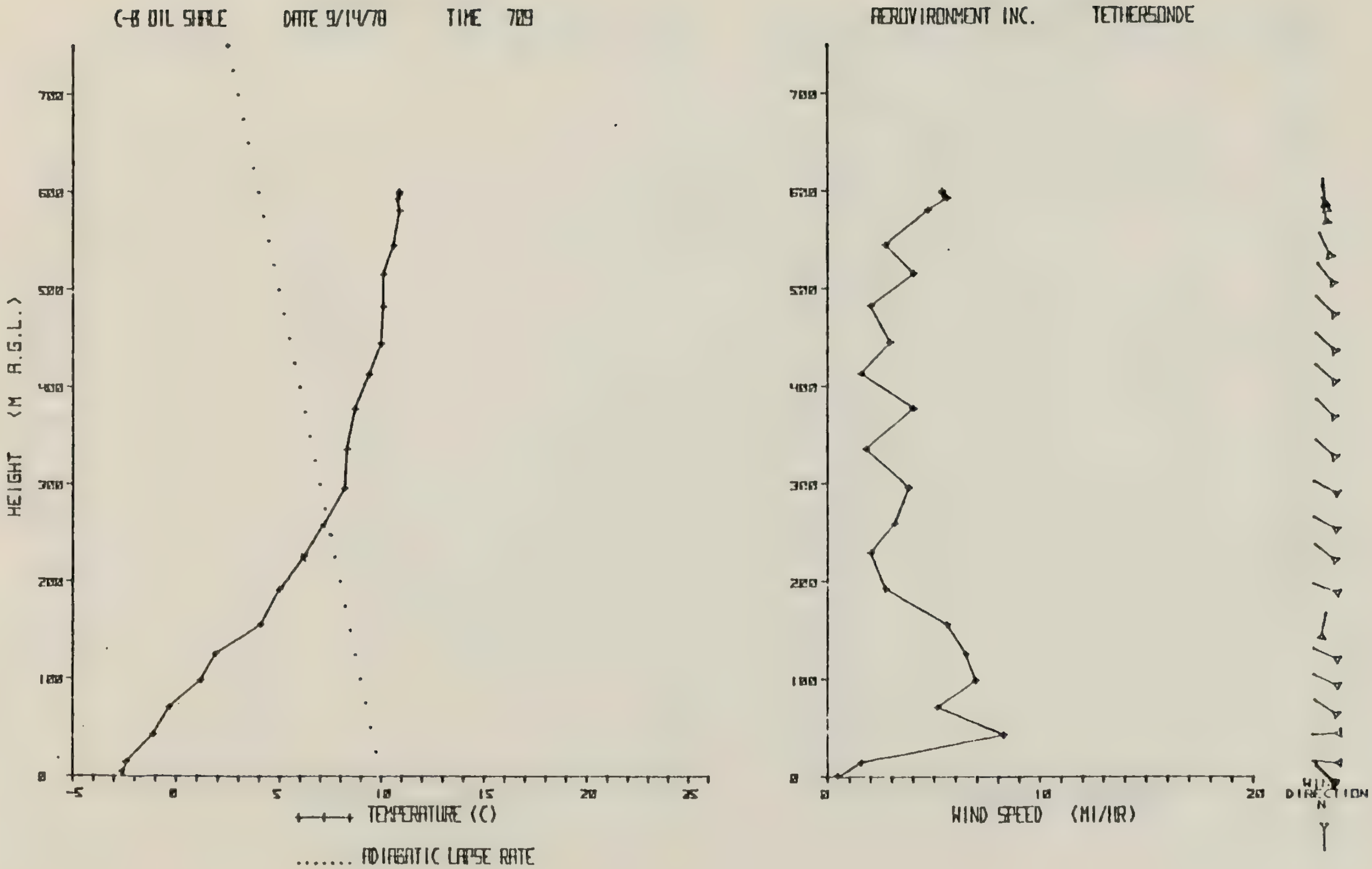
C-B OIL SHALE DATE 9/14/78 TIME 605

AEROVIRONMENT INC. TETHERSONDE

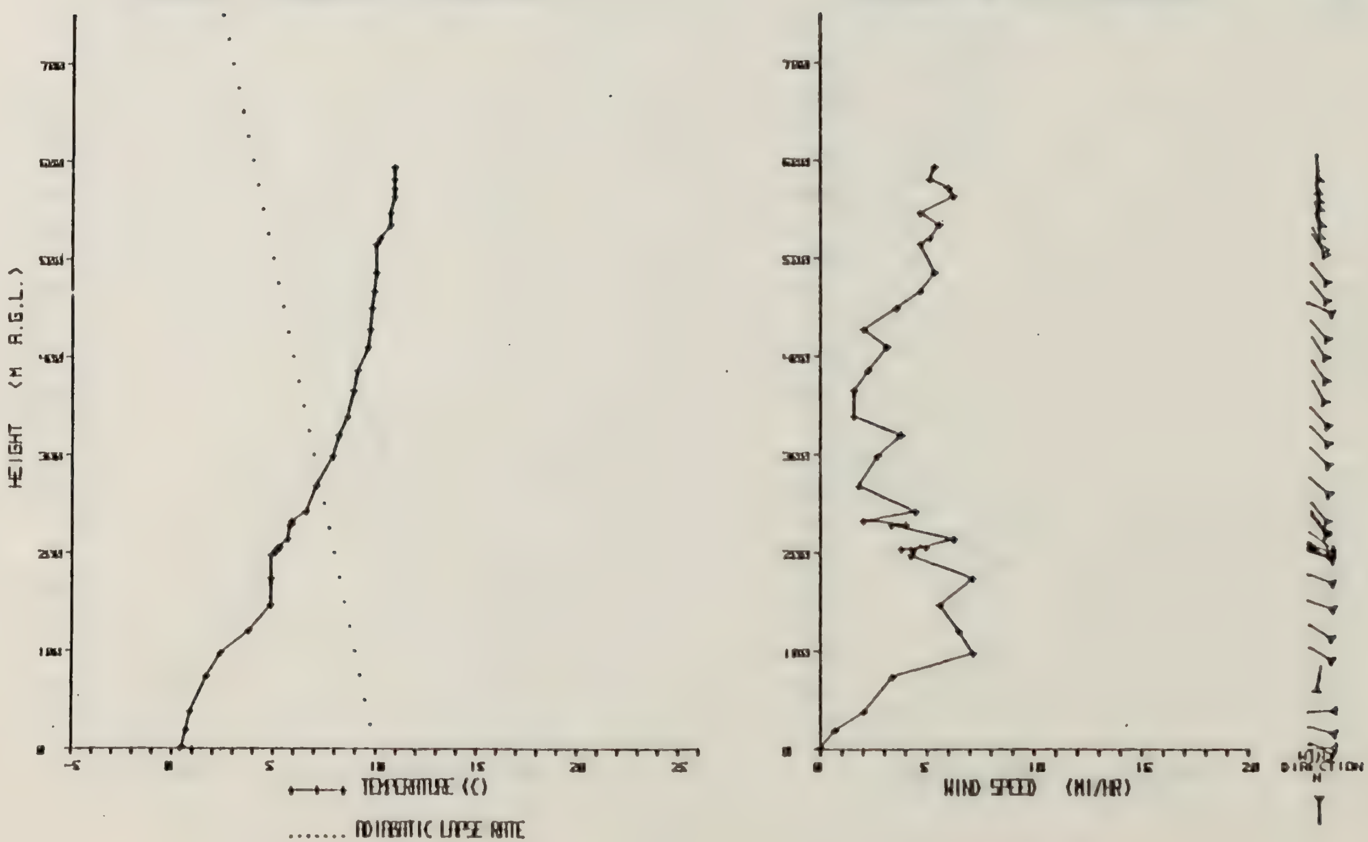


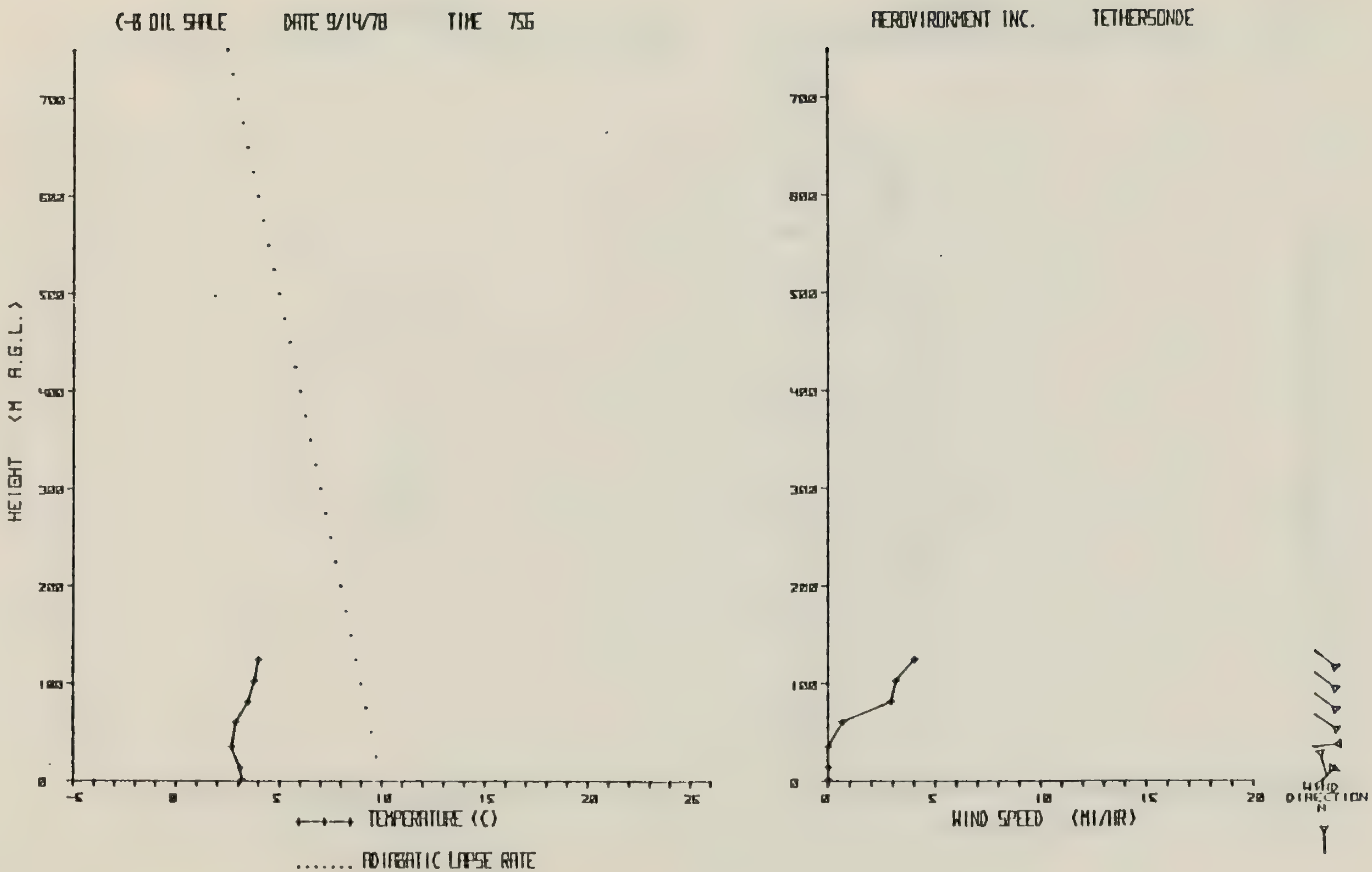


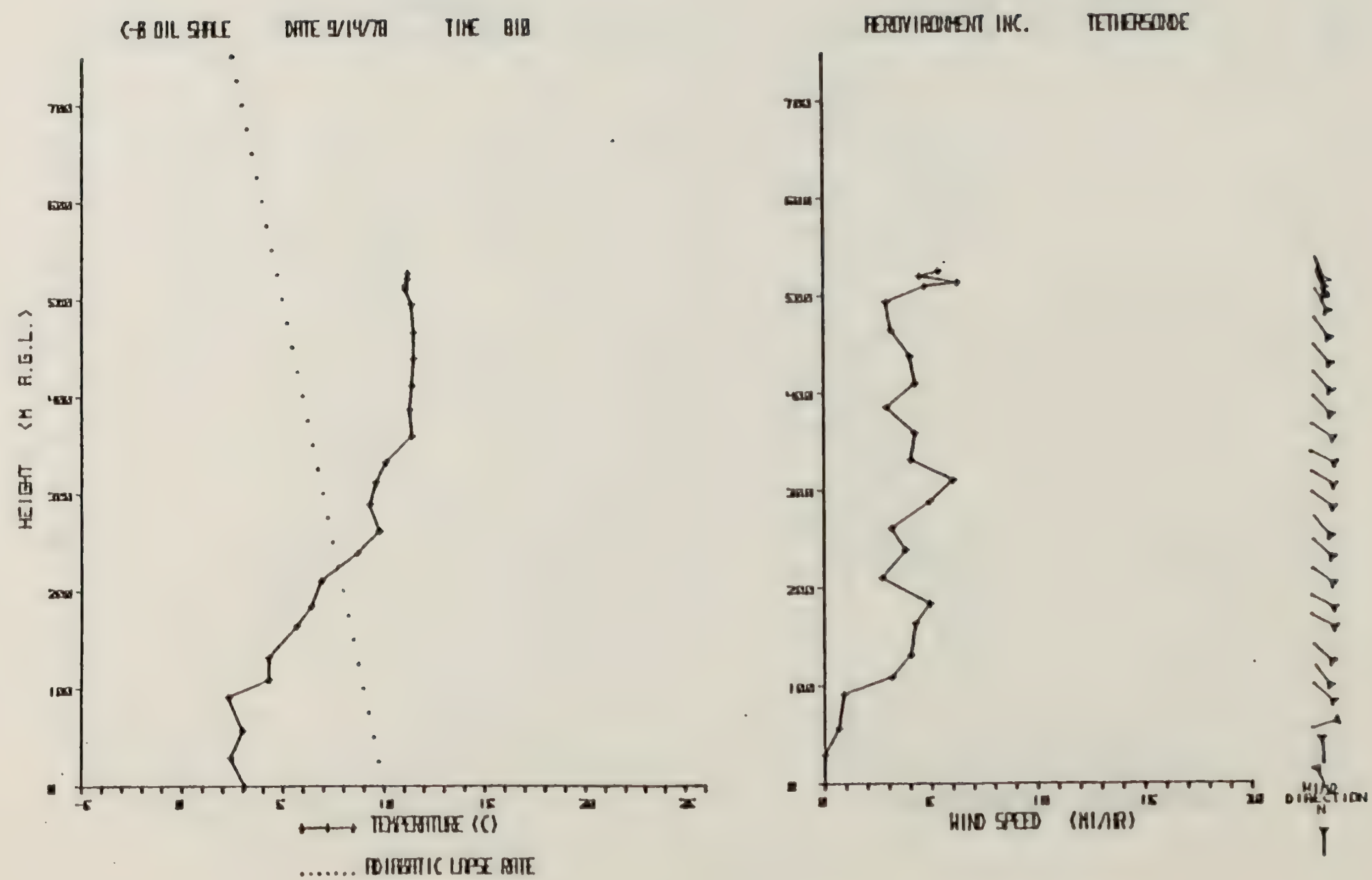
C-B OIL SHALE DATE 9/14/78 TIME 618
AEROVIRONMENT INC. TETHERSONDE
HEIGHT (M A.G.L.)
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N


C-B OIL SHALE
DATE 9/14/78
TIME 709
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
0
100
200
300
400
500
600
700
-5
0
5
10
15
20
25
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N

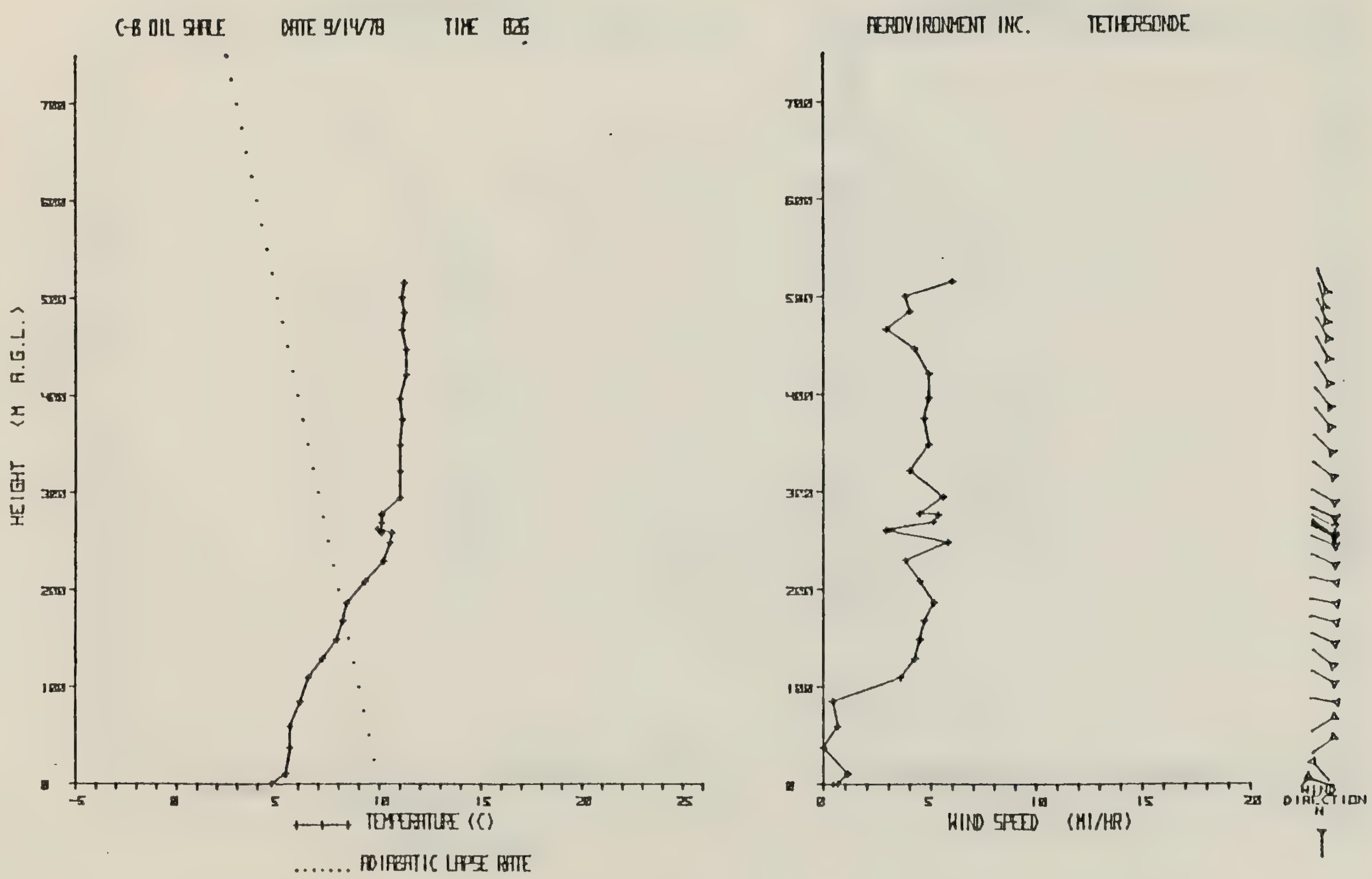
C-B OIL SHALE   DATE 9/14/78   TIME 721   AEROVIRONMENT INC.   TETHERSONDE



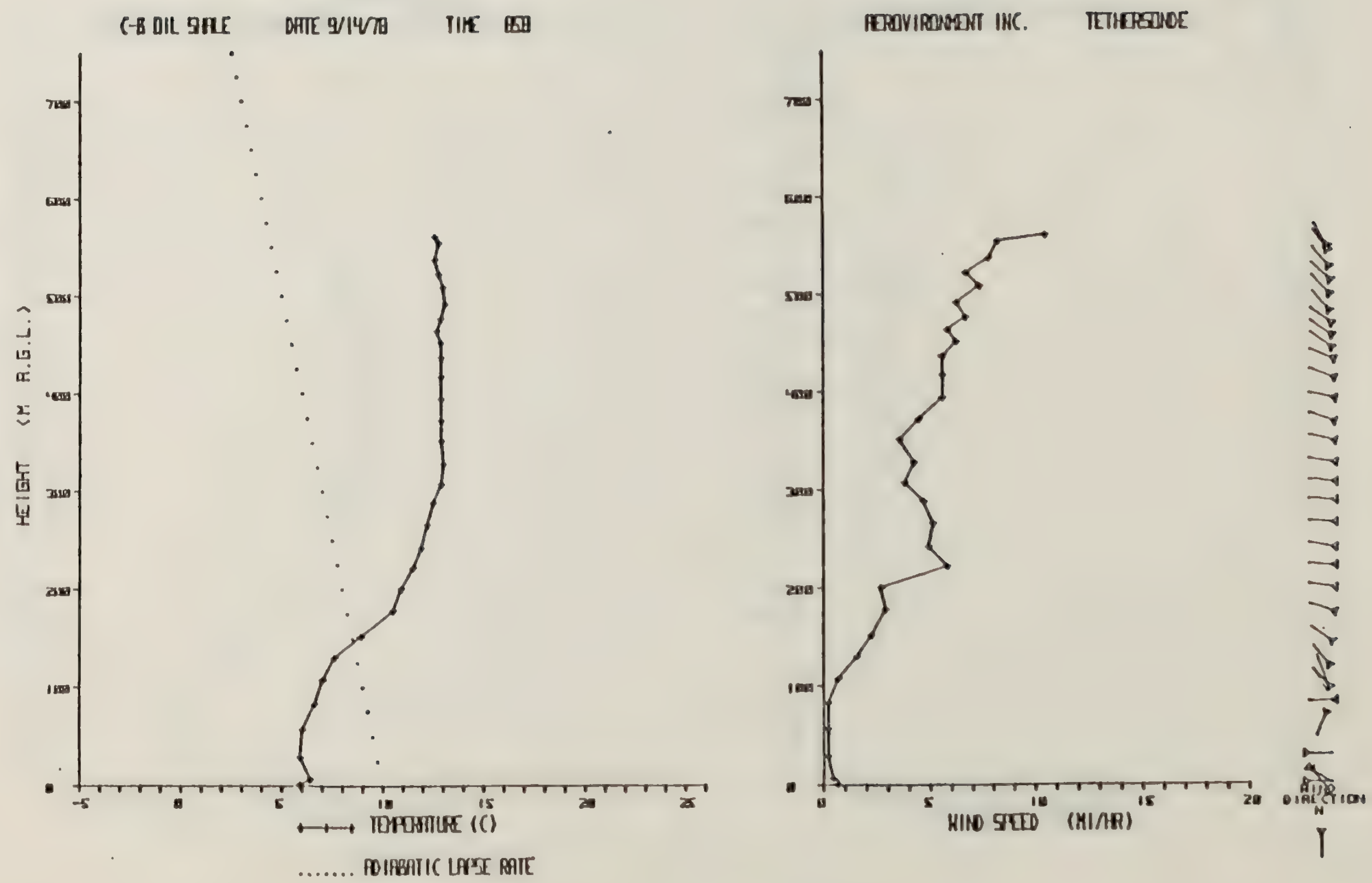

C-B OIL SHALE
DATE 9/14/78
TIME 756
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
0
100
200
300
400
500
600
700
-5
0
5
10
15
20
25
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N



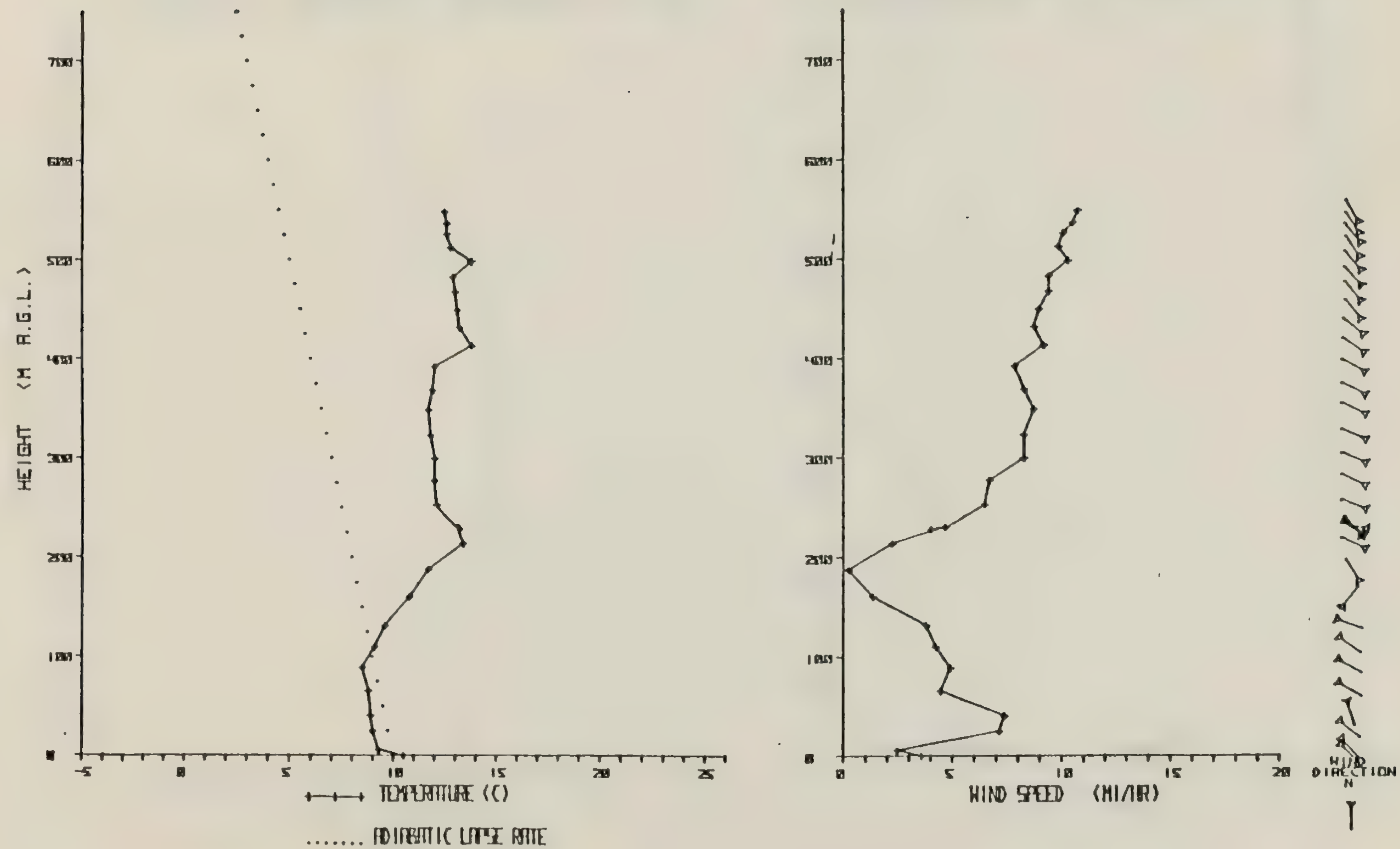
C-B OIL SHALE
DATE 9/14/78
TIME 810
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
0
100
200
300
400
500
600
700
-5
0
5
10
15
20
25
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N

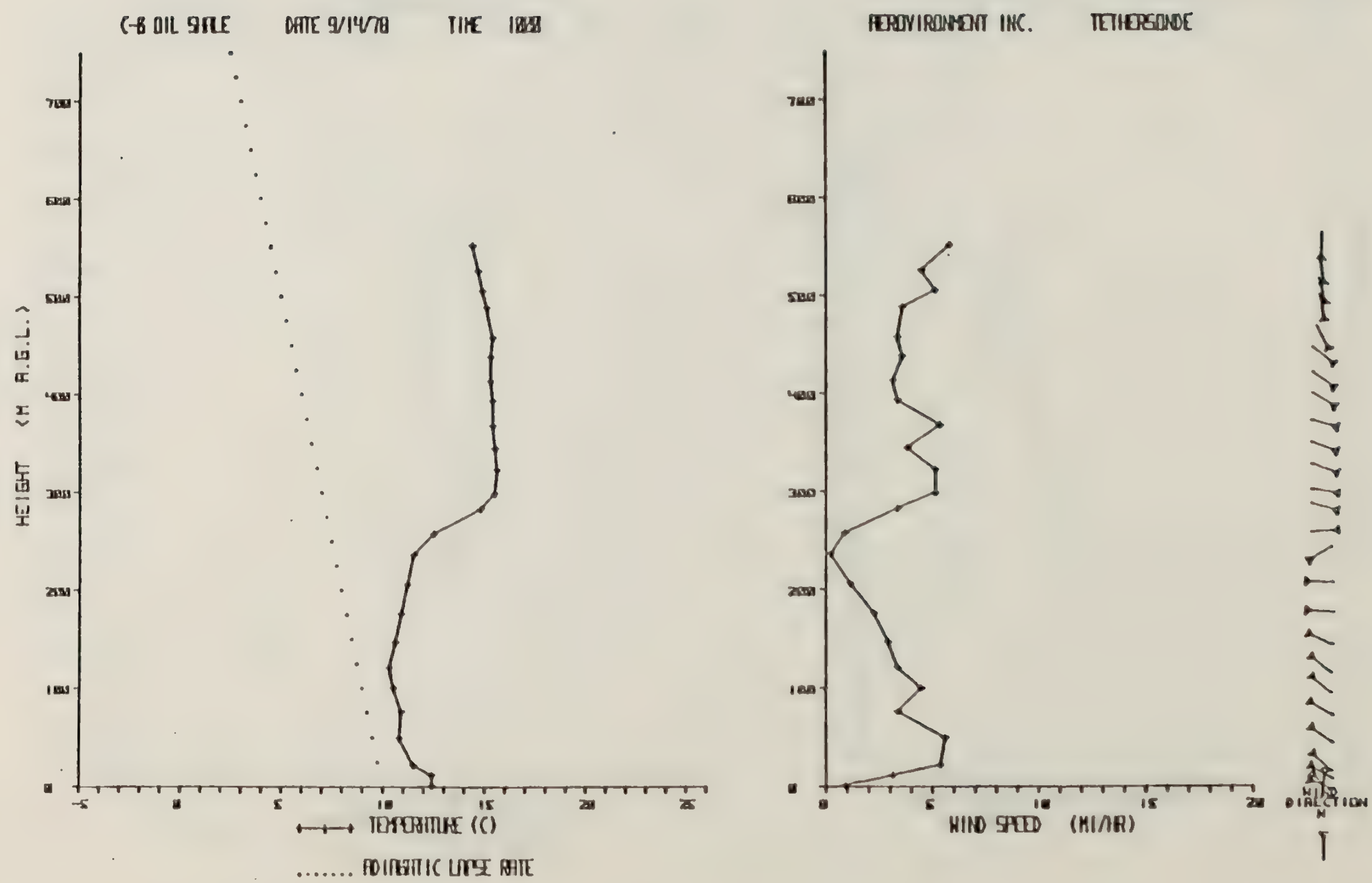


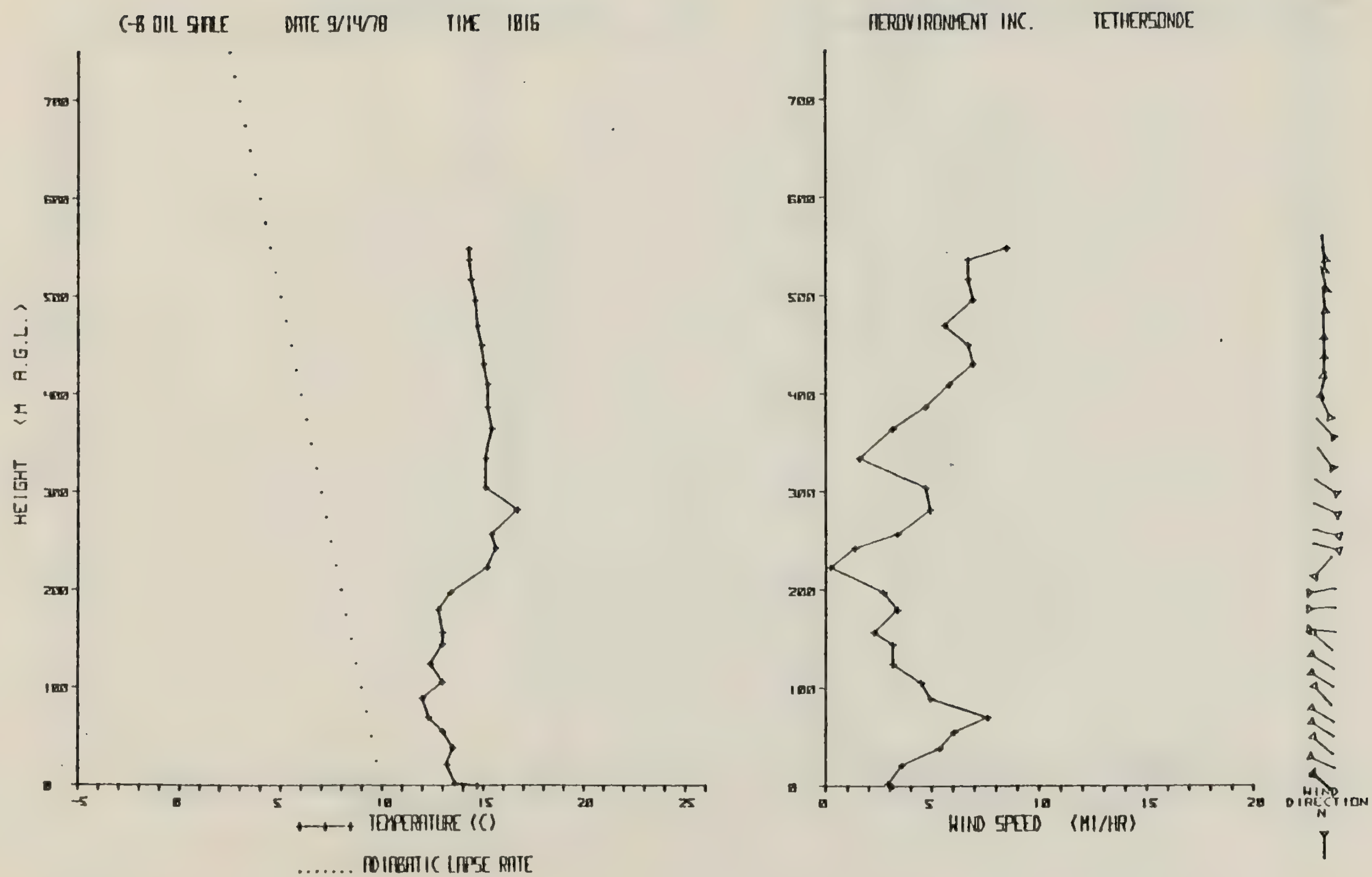
C-B OIL SHALE
DATE 9/14/78
TIME 826
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
0
100
200
300
400
500
600
700
-5
0
5
10
15
20
25
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N


C-B OIL SHALE
DATE 9/14/78
TIME 850
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
-5
0
5
10
15
20
25
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N

C-B OIL SHALE   DATE 9/14/70   TIME 913   AEROVIRONMENT INC.   TETHERSONDE

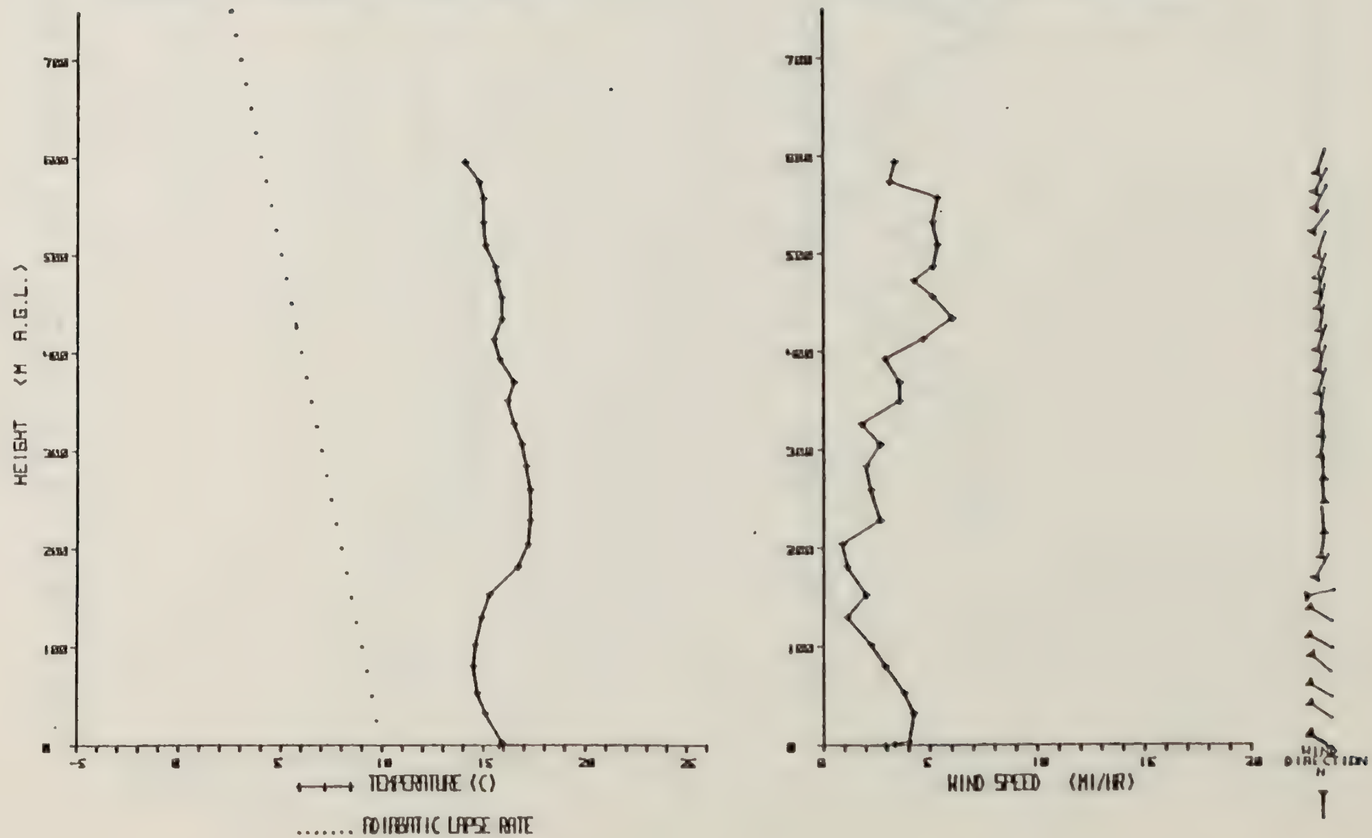



C-B OIL SHALE
DATE 9/14/78
TIME
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
TEMPERATURE (C)
ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N



C-B OIL SHALE
DATE 9/14/78
TIME 1816
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
0
100
200
300
400
500
600
700
-5
0
5
10
15
20
25
TEMPERATURE (C)
ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N

C-B OIL SHALE DATE 9/14/78 TIME 1857 AEROVIRONMENT INC. TETHERSONDE



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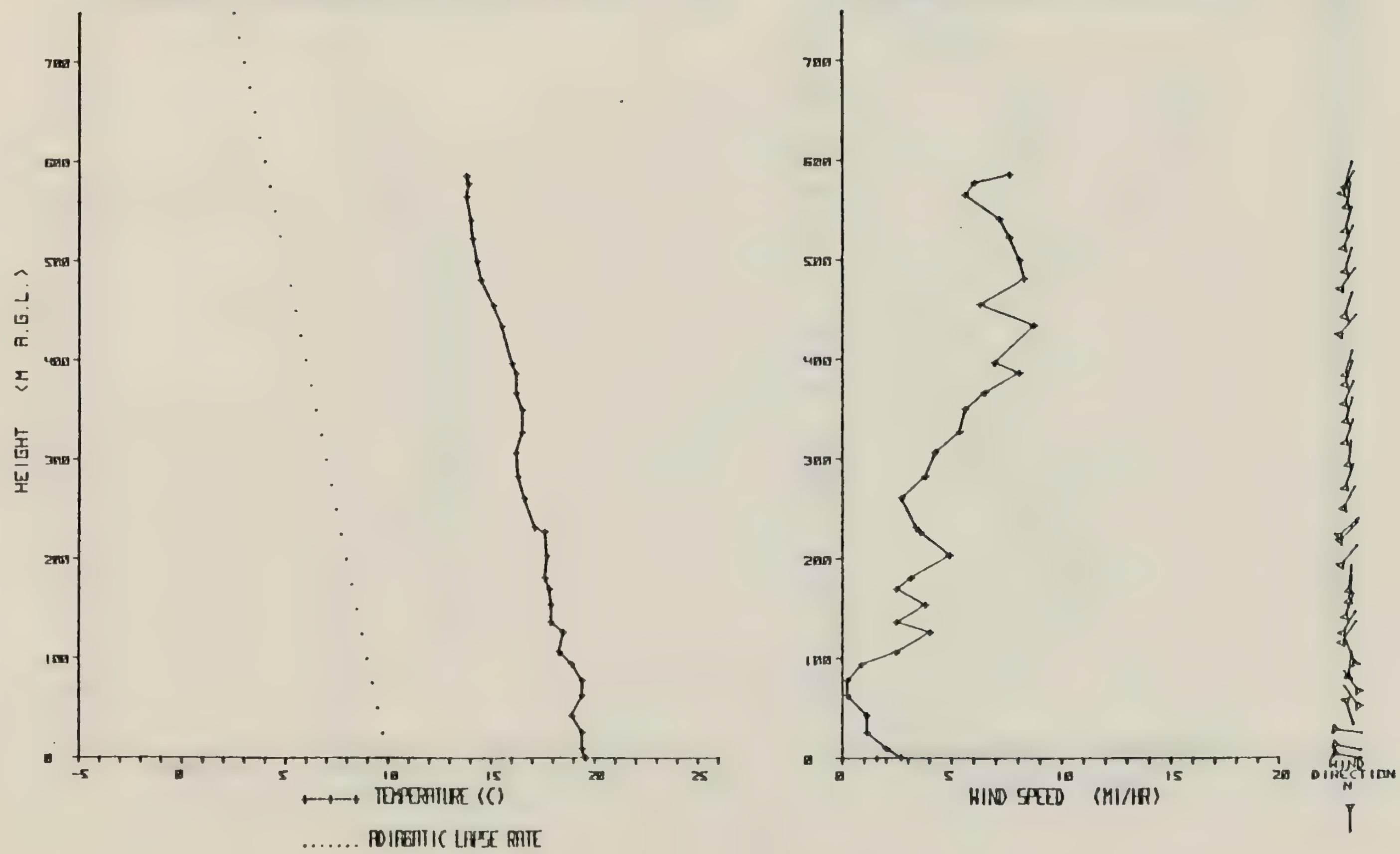
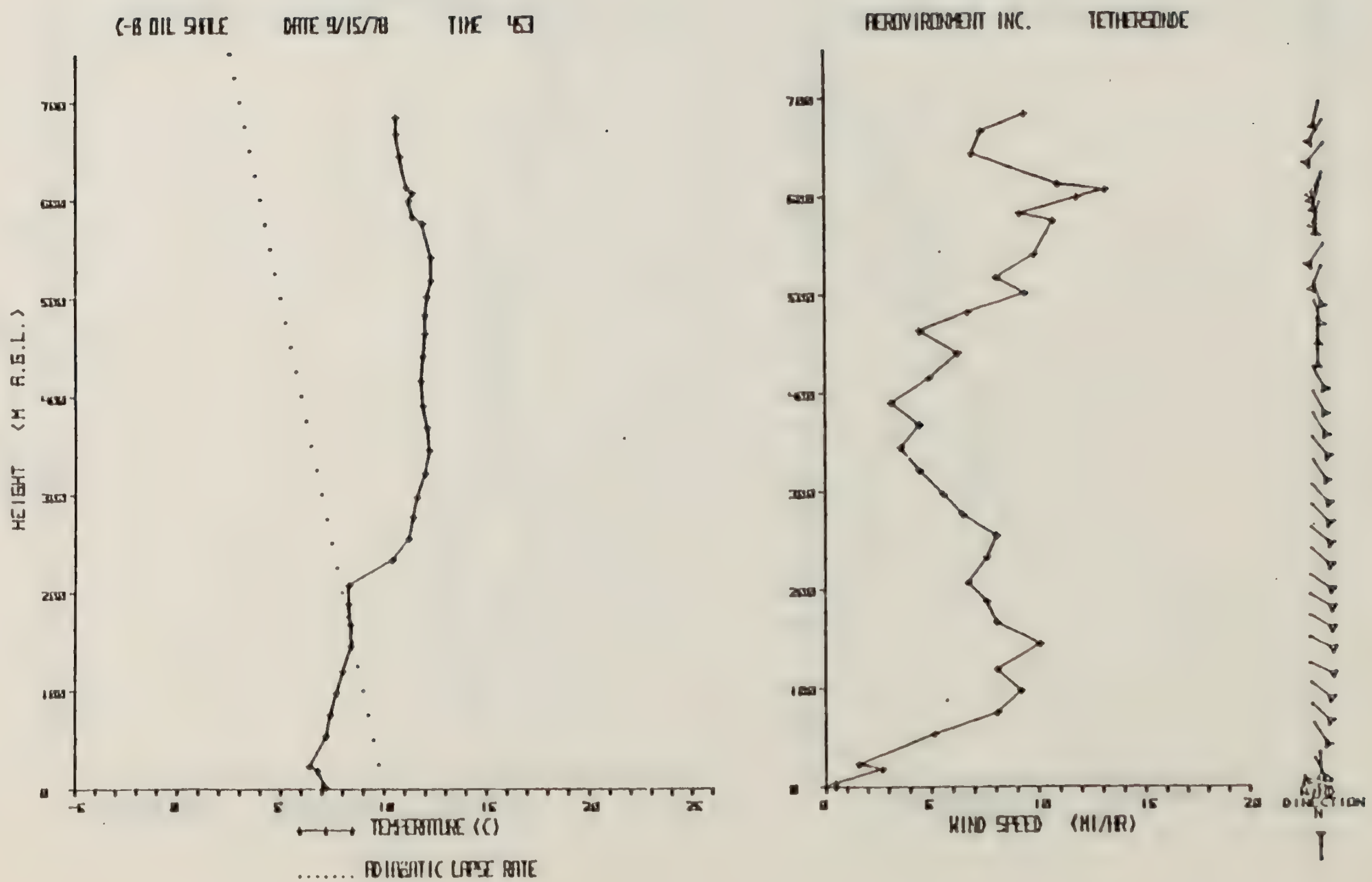
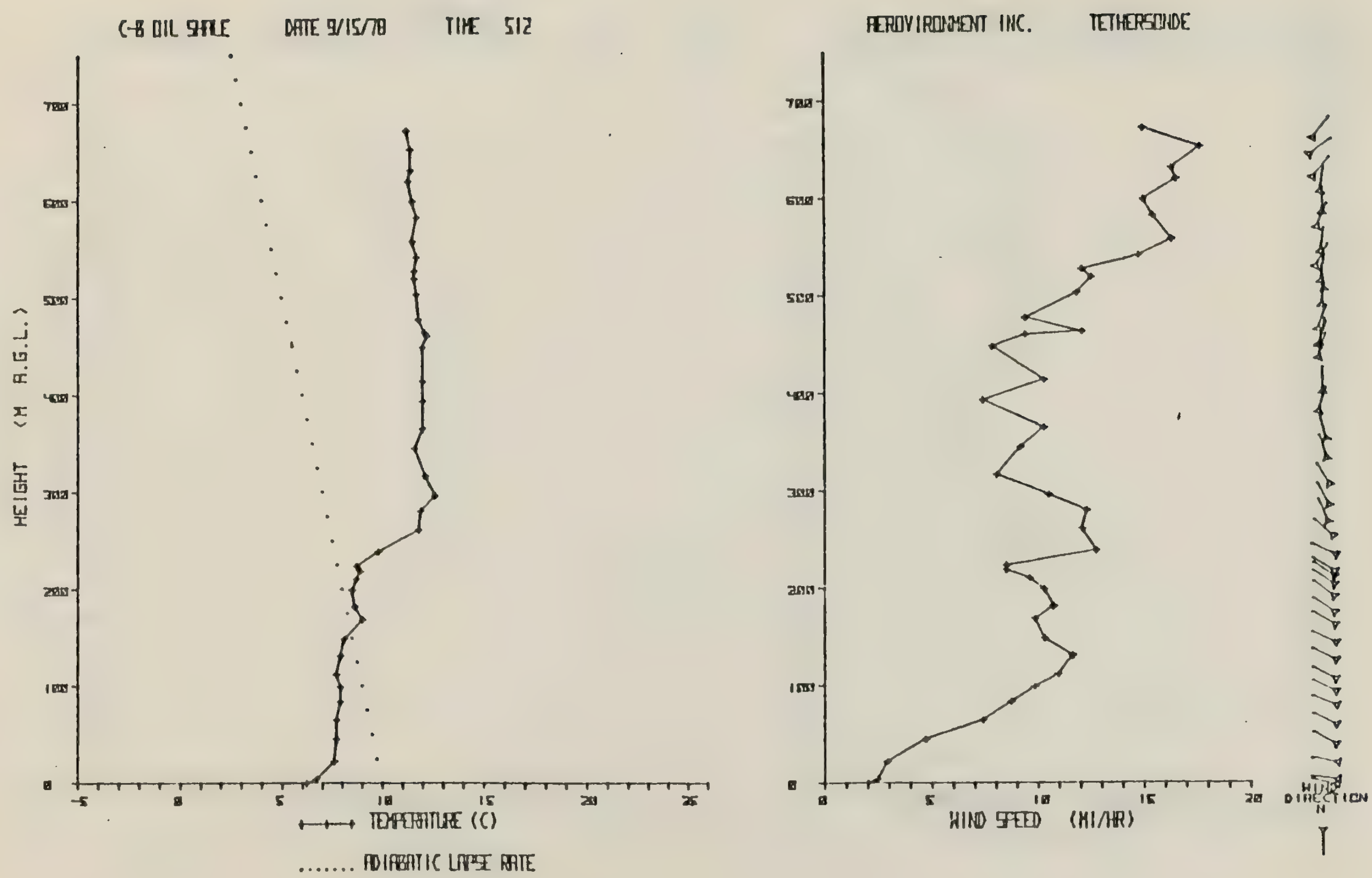
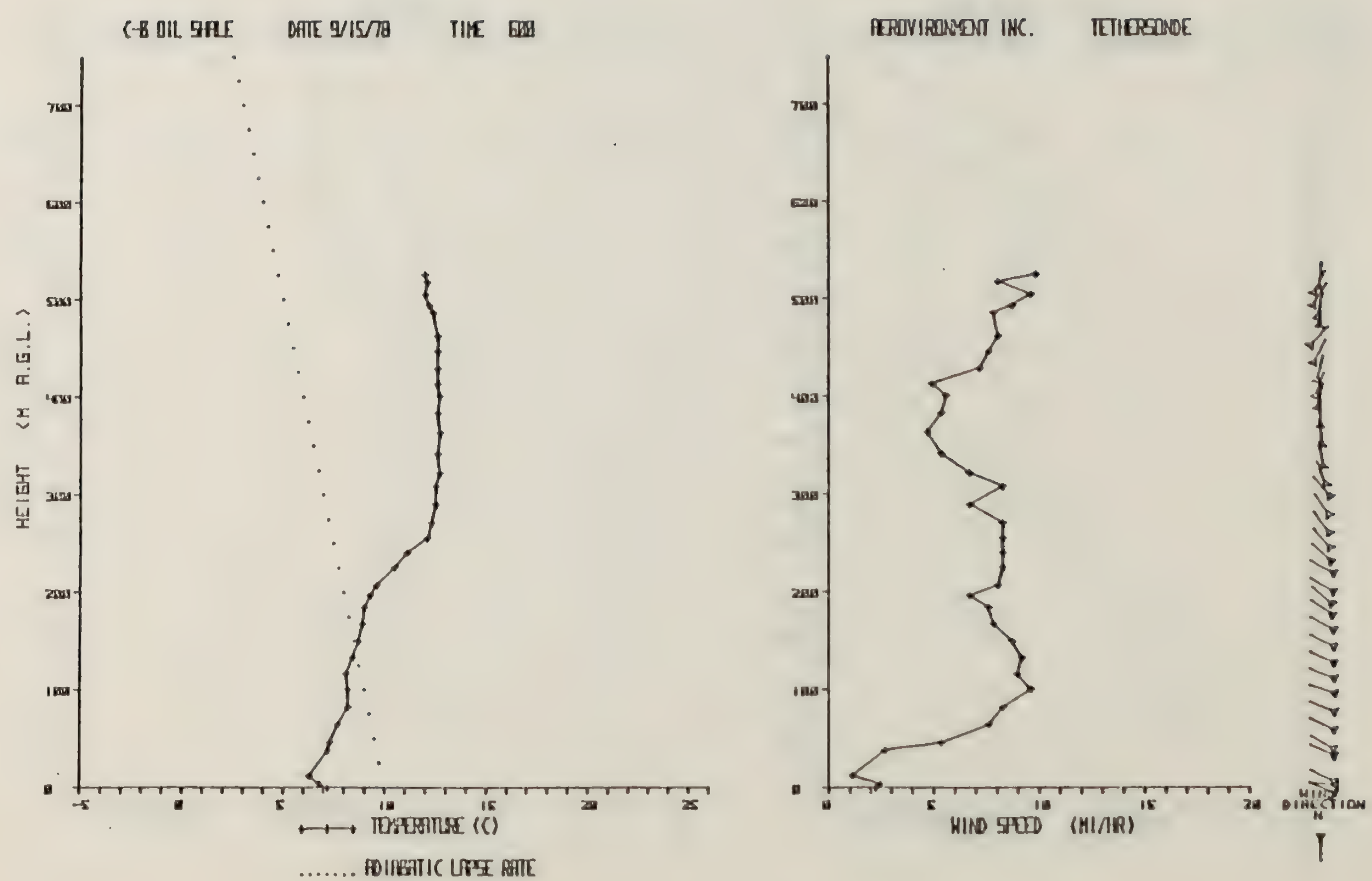




C-B OIL SHALE DATE 9/15/78 TIME 453
AEROVIRONMENT INC. TETHERSONDE
HEIGHT (M A.G.L.)
TEMPERATURE (C)
ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N



C-B OIL SHALE
DATE 9/15/78
TIME 512
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
0
100
200
300
400
500
600
700
-5
0
5
10
15
20
25
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N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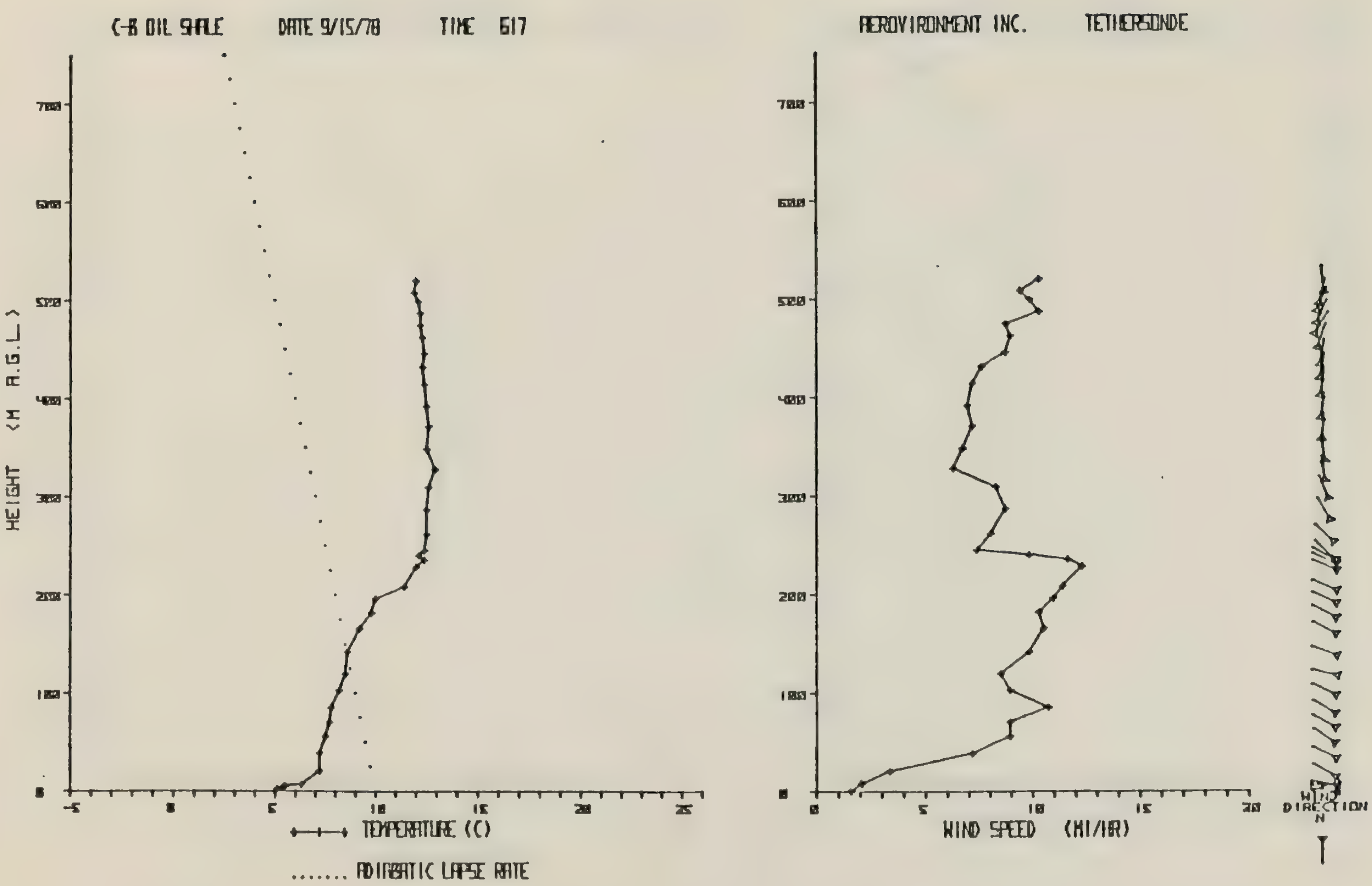
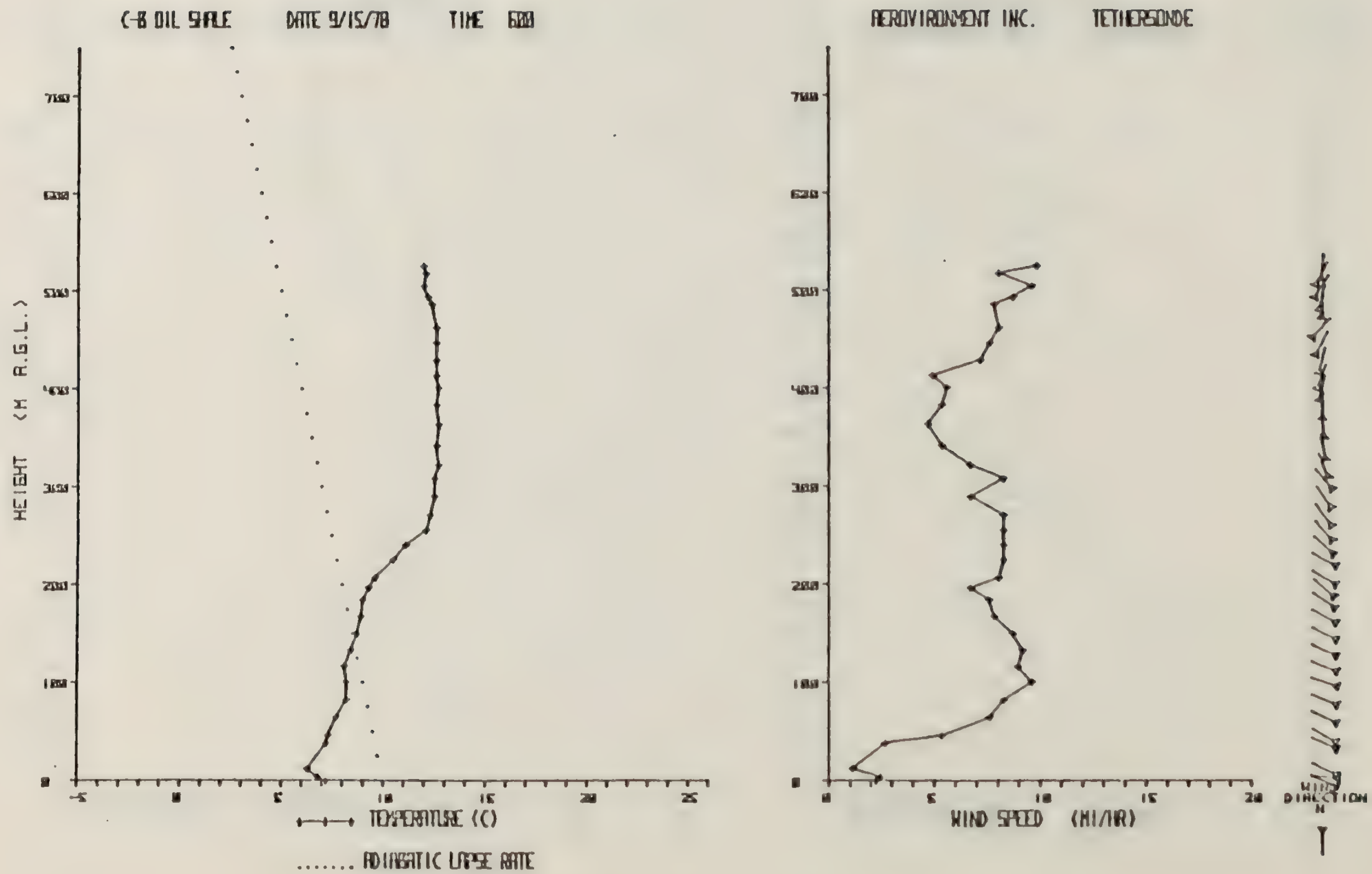
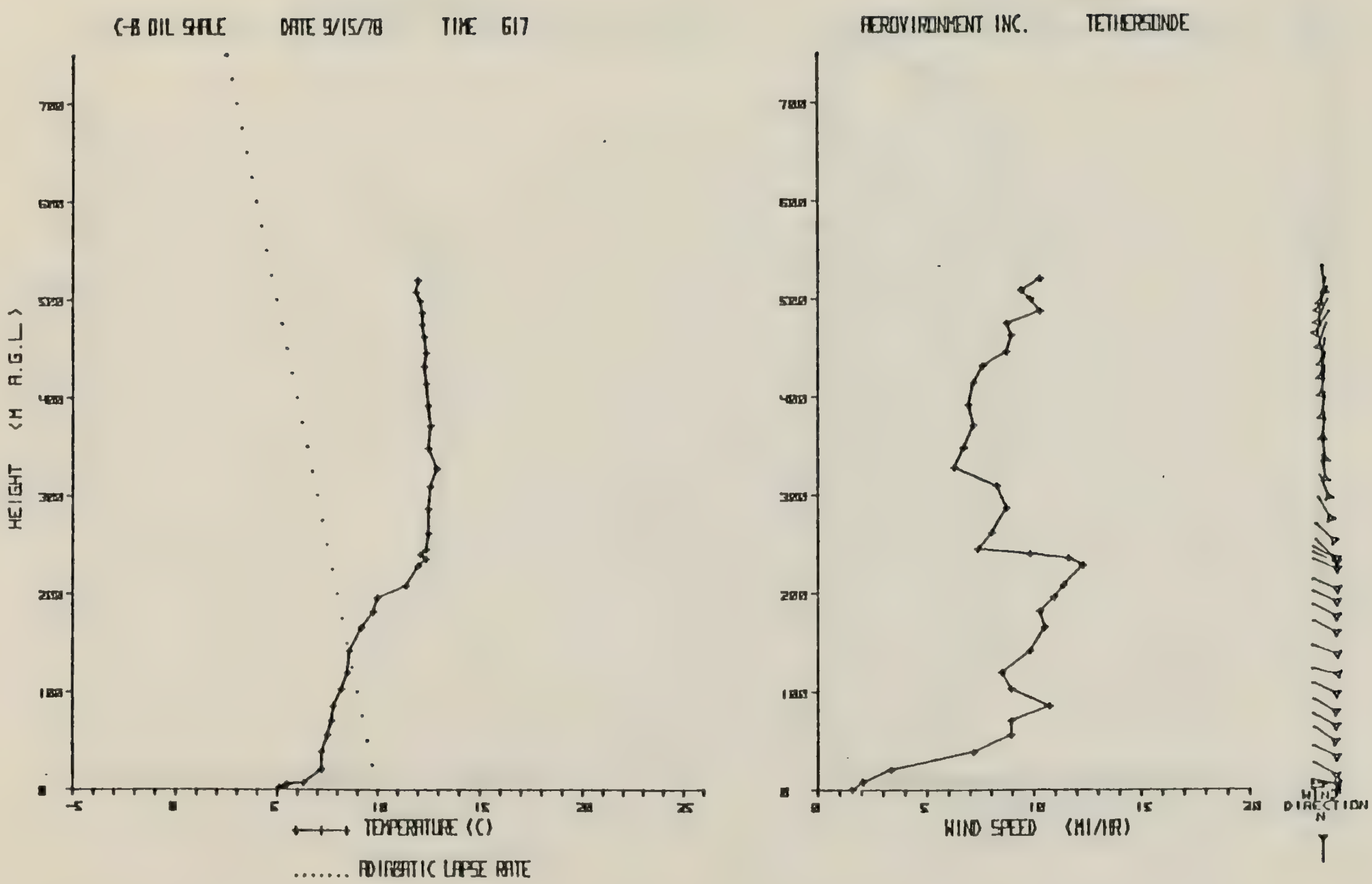
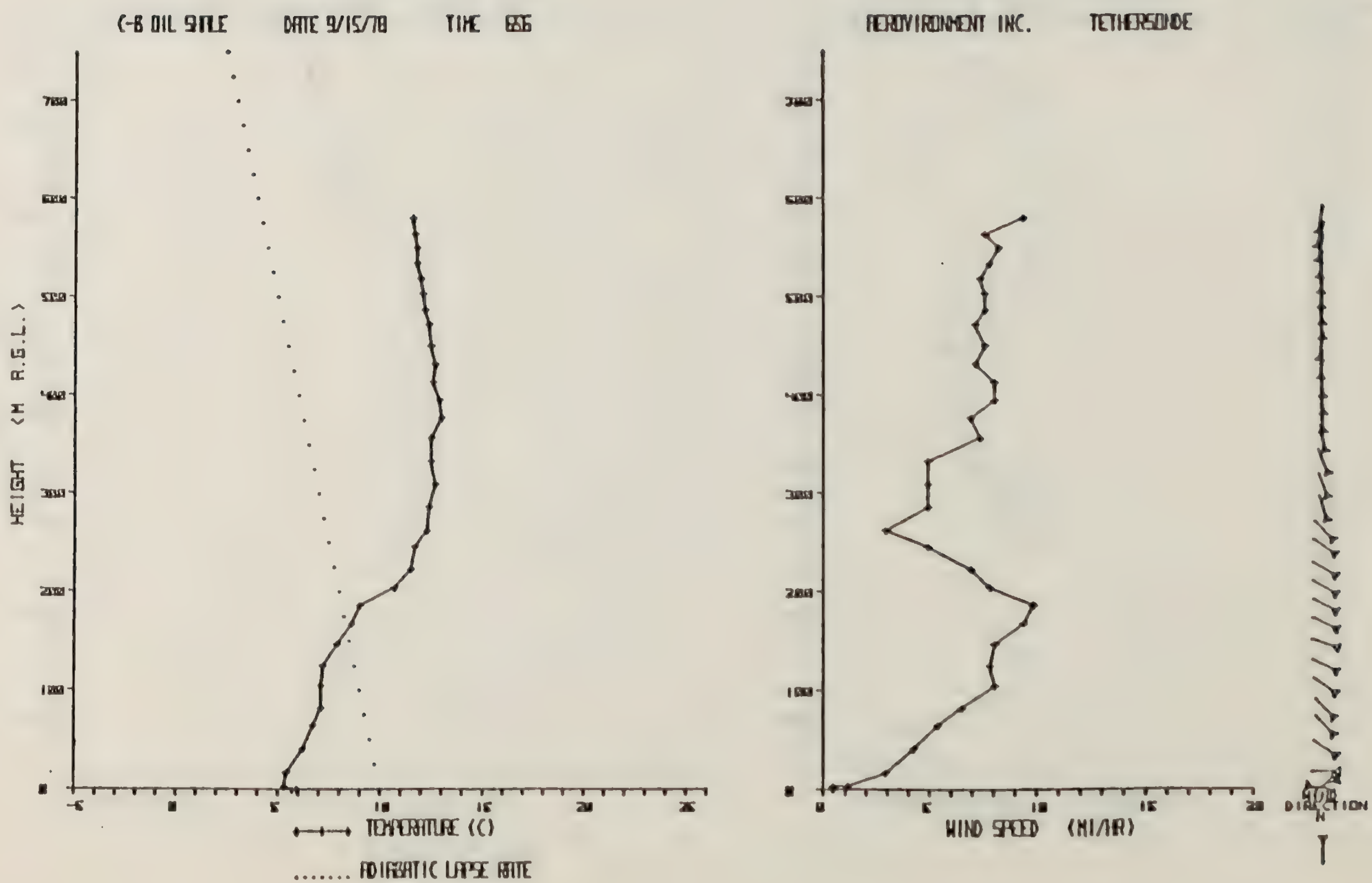
AEROVIRONMENT INC. TETHERSONDE
HEIGHT (M A.G.L.)
TEMPERATURE (C)
ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N

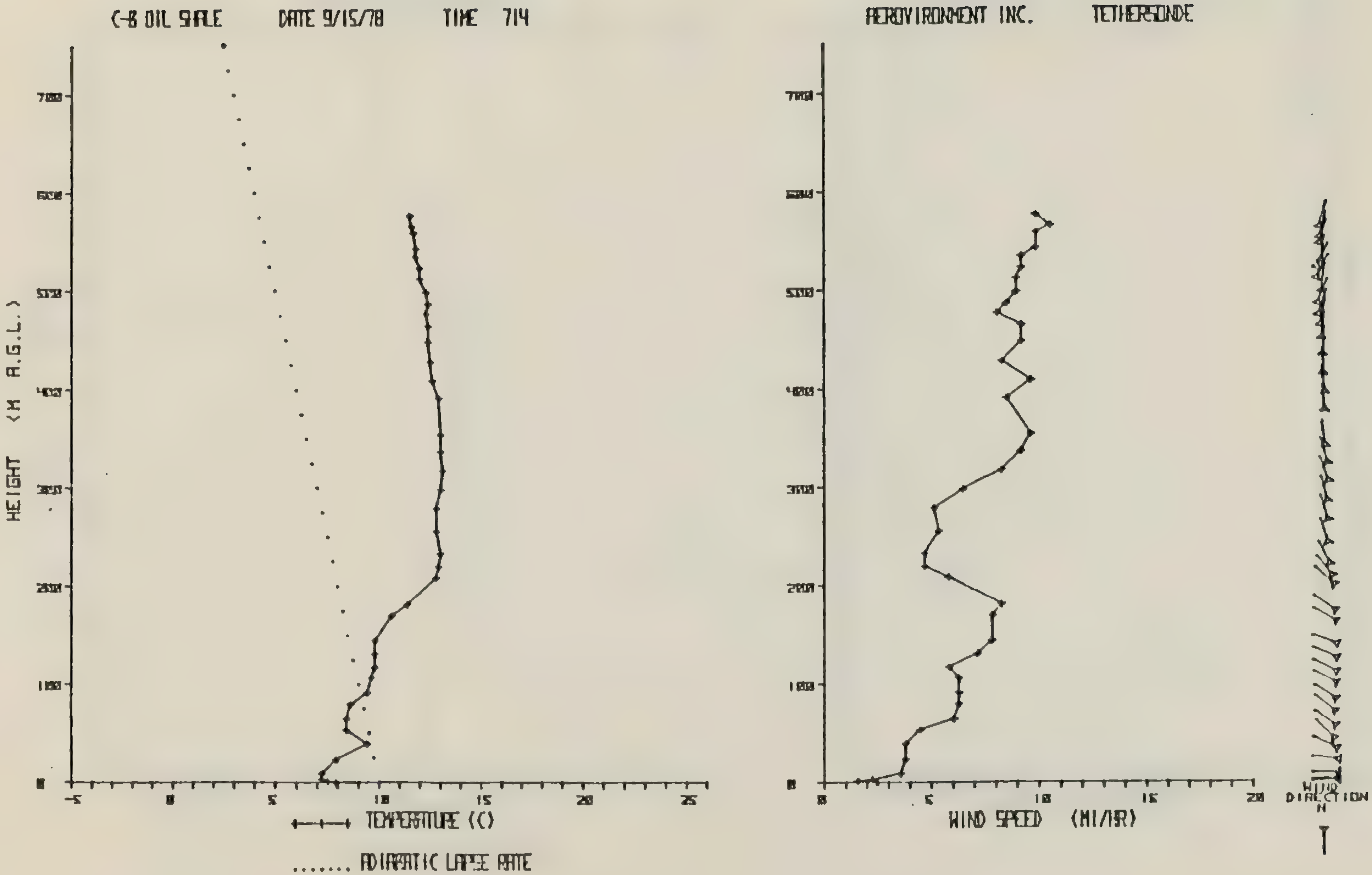

C-B OIL SHALE
DATE 9/15/78
TIME 617
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N


C-B OIL SHALE DATE 9/15/78 TIME 600
AEROVIRONMENT INC. TETHERSONDE
HEIGHT (M A.G.L.)
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N

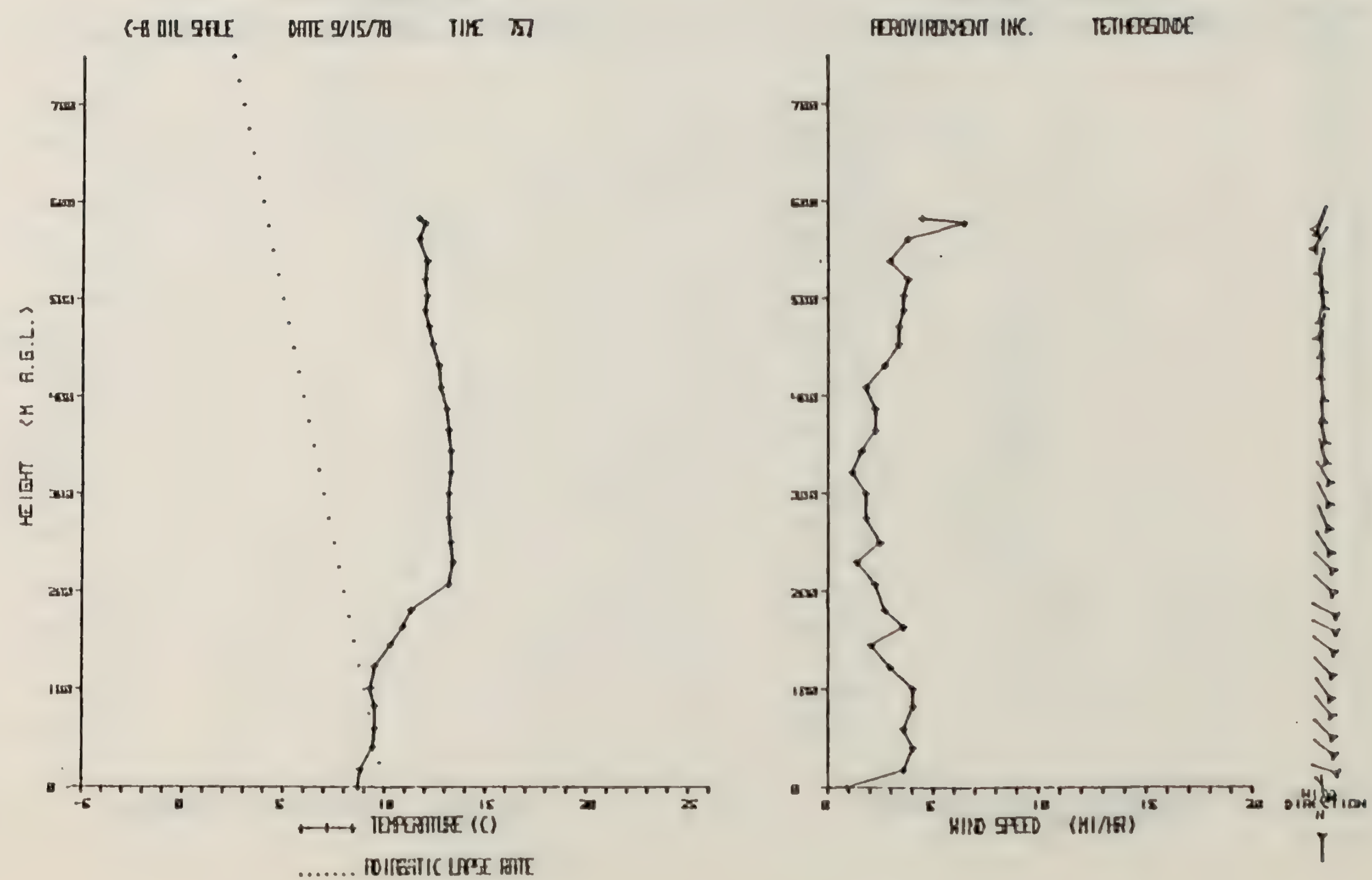


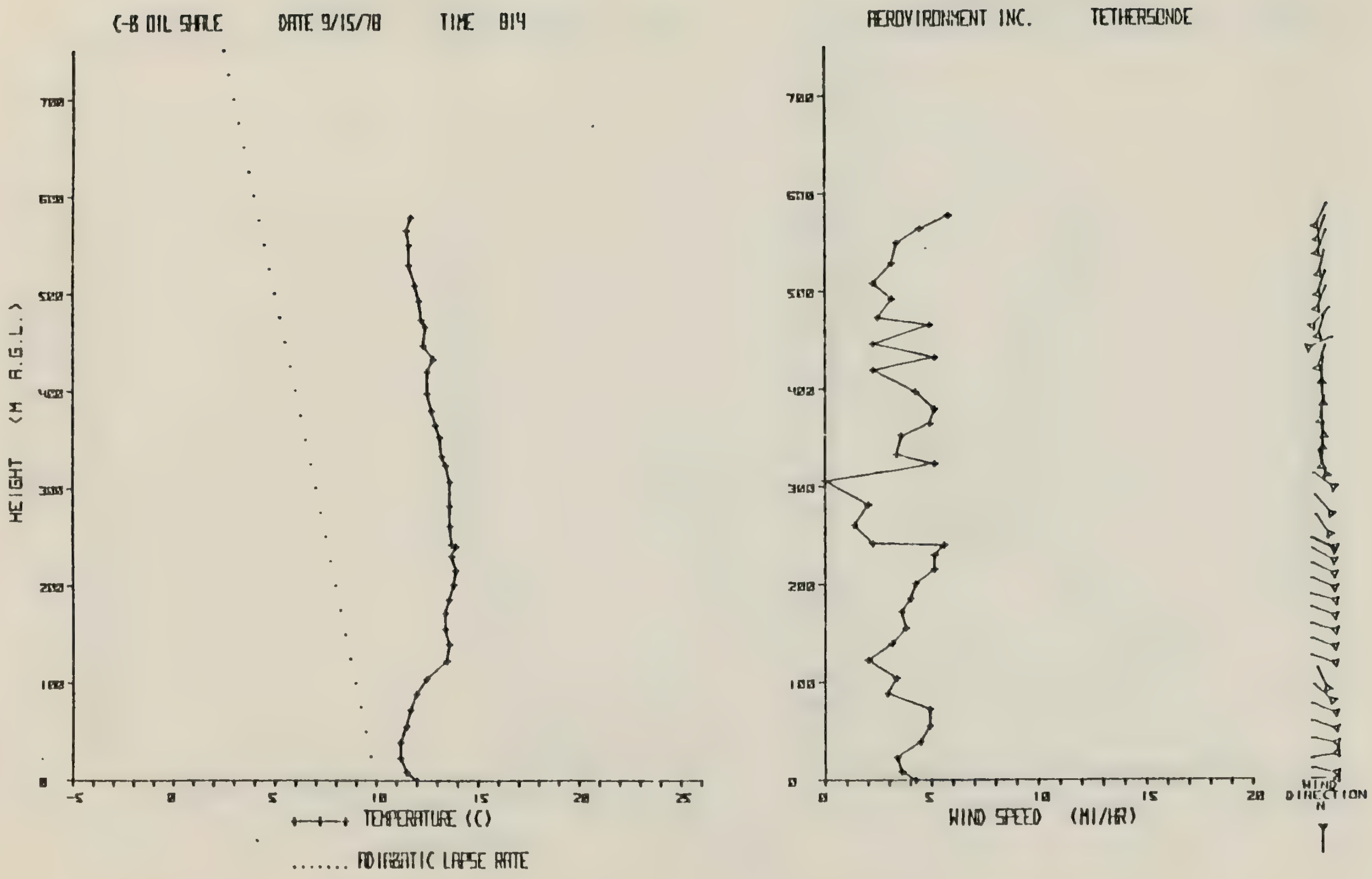
C-B OIL SHALE DATE 9/15/78 TIME 617
AEROVIRONMENT INC. TETHERSONDE
HEIGHT (M A.G.L.)
700
600
500
400
300
200
100
0
-5
0
5
10
15
20
25
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N

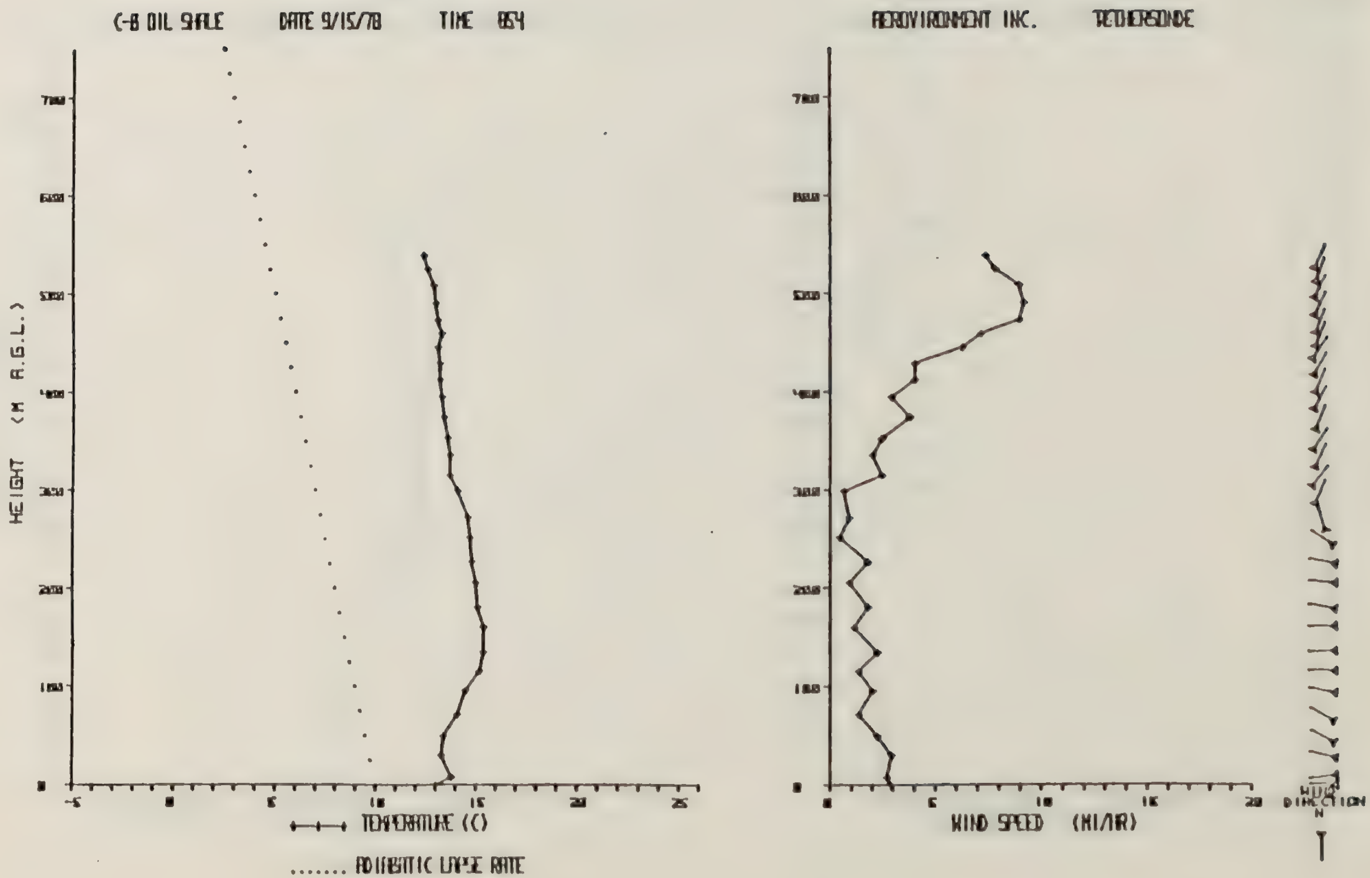

C-B OIL SHALE
DATE 9/15/78
TIME 656
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
TEMPERATURE (C)
ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
DIRECTION
N

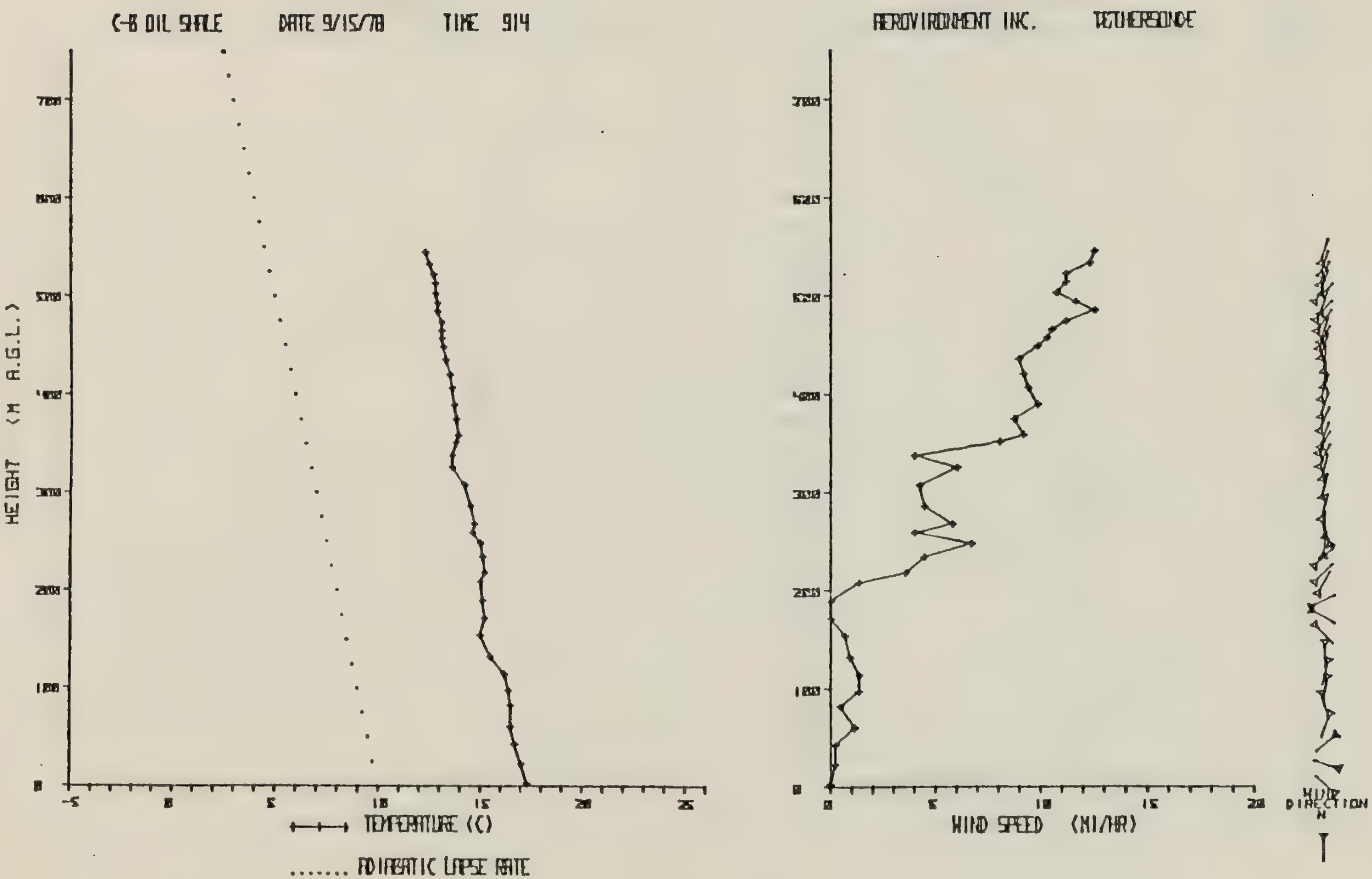


C-B OIL SHALE
DATE 9/15/78
TIME 714
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
-5
0
5
10
15
20
25
TEMPERATURE (C)
ADIABATIC LAPSE RATE
0
5
10
15
20
WIND SPEED (MI/HR)
WIND DIRECTION
N


C-B OIL SHALE DATE 9/15/78 TIME 757
AEROVIRONMENT INC. TETHERSONDE
HEIGHT (M A.G.L.)
TEMPERATURE (C)
ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N

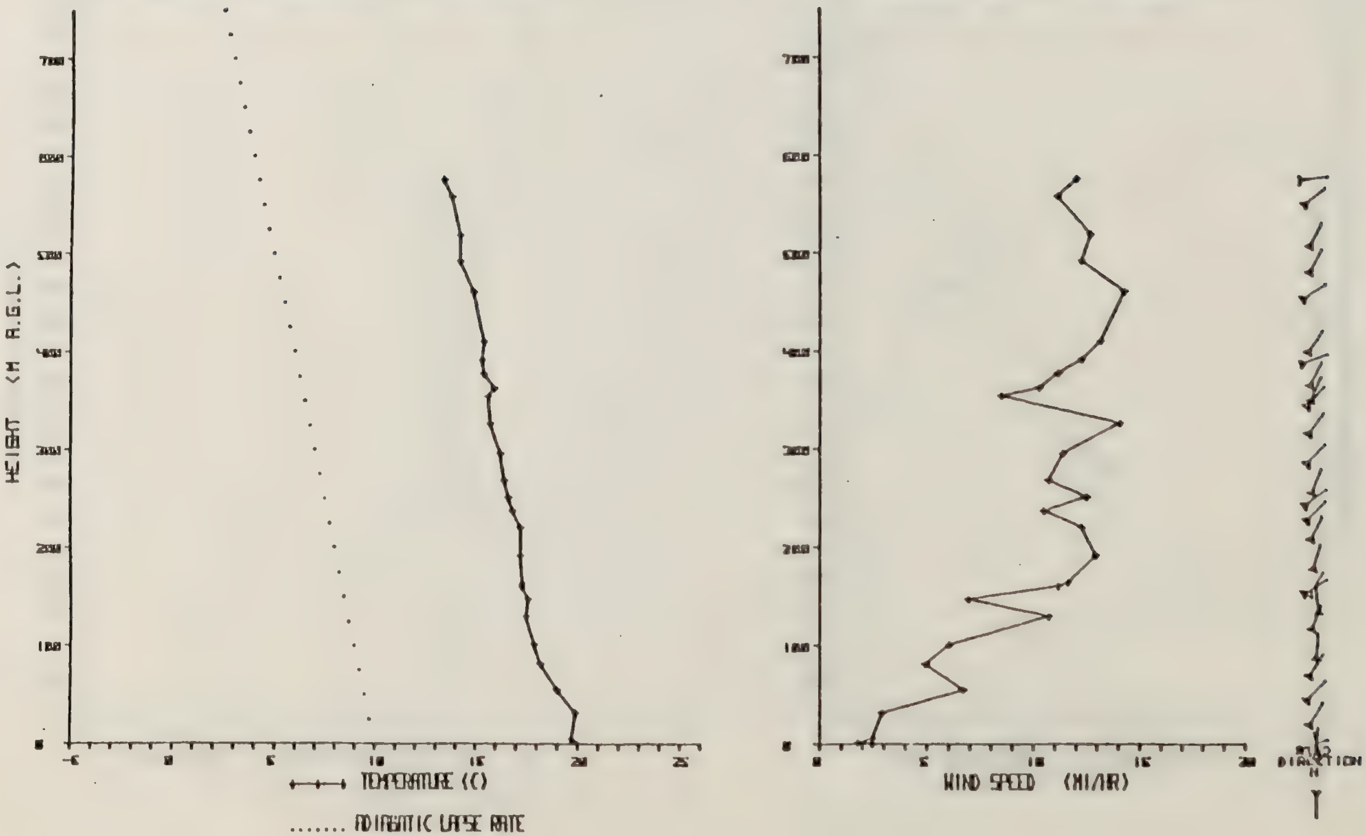

C-B OIL SHALE DATE 9/15/78 TIME 814
AEROVIRONMENT INC. TETHERSONDE
HEIGHT (M A.G.L.)
0
100
200
300
400
500
600
700
-5
0
5
10
15
20
25
TEMPERATURE (C)
ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N


C-B OIL SHALE
DATE 9/15/78
TIME 854
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
WIND SPEED (MI/HR)
WIND DIRECTION
N


C-B OIL SHALE
DATE 9/15/78
TIME 914
AEROVIRONMENT INC.
TETHERSONDE
HEIGHT (M A.G.L.)
-5
0
5
10
15
20
25
TEMPERATURE (C)
.... ADIABATIC LAPSE RATE
0
5
10
15
20
WIND SPEED (MI/HR)
WIND DIRECTION
N

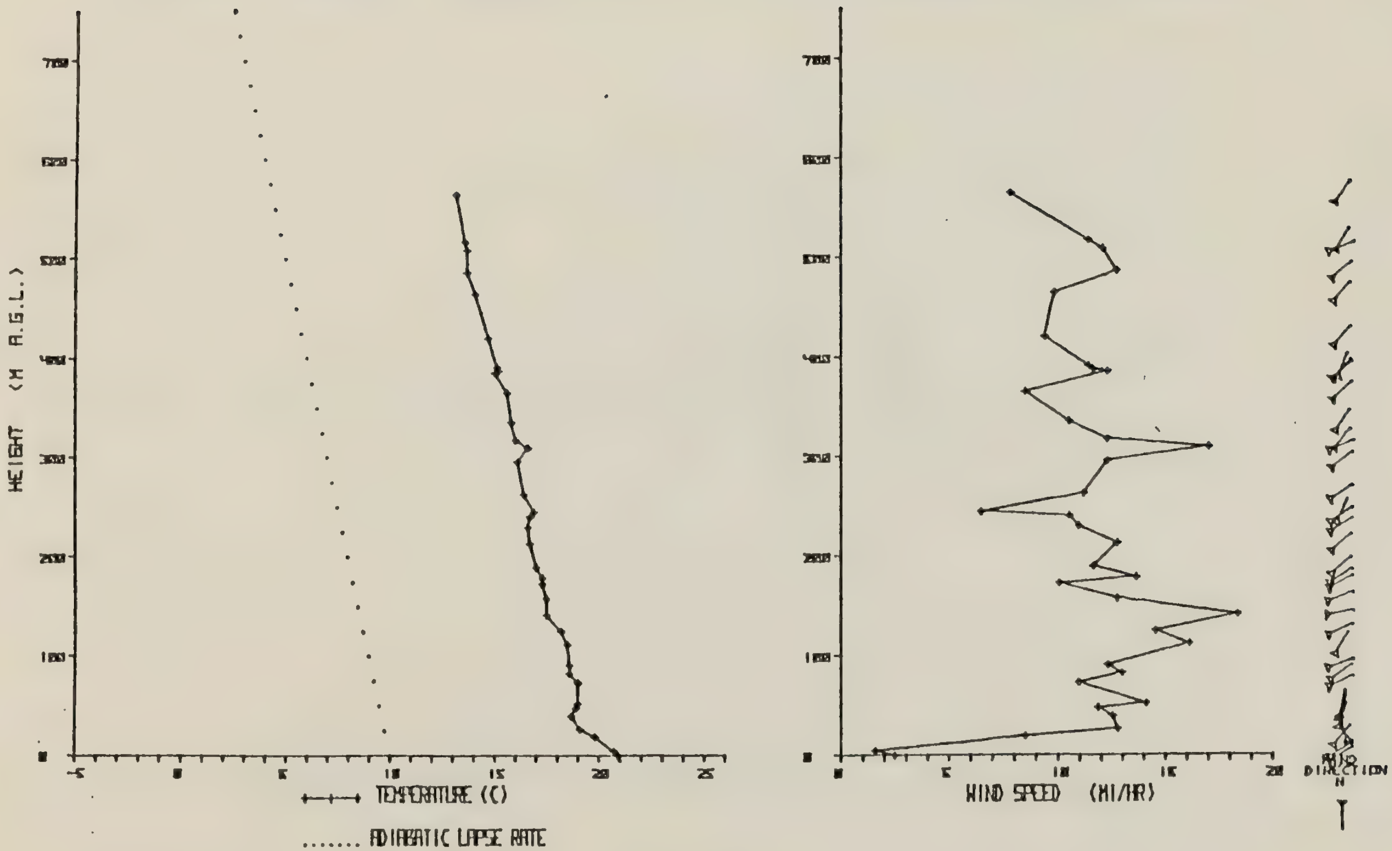
C-B OIL SHALE DATE 9/15/78 TIME 955

AEROVIRONMENT INC. TETHERSONDE



C-B OIL SHALE DATE 9/15/78 TIME 1015

AEROVIRONMENT INC. TETHERSONDE



APPENDIX B

Tracer Gas Release Data

TABLE B-1. Release site data, 14 September 1978, release rate 28.8 lbs/hr, height of release approximately 100 m (330 feet).

Time	Cylinder Weight (lbs)	Estimated Wind
0412	279.5	SE
0427	273.0	SE
0442	266.5	S
0458	259.5	ESE
0515	252.5	S
0535	245.0	SW
0545	240.5	SW
0600	235.5	W
0612	230.5	N
0627	224.5	SE
0642	217.5	SE
0657	211.5	SSE
0712	205.0	SSE
0727	199.0	SE
0742	193.5	E
0757	186.0	E
0812	179.5	SE
0827	173.5	ESE
0842	171.5	ESE
0857	263.0	E
0912	256.5	ENE
0927	250.5	E
0942	244.3	ENE
0957	237.4	NNE
1012	231.1	NNE
1027	225.5	ENE
1042	219.5	N
1057	212.5	SW
1100	210.5	S

TABLE B-2. Release site data, 15 September 1978, release rate 28.0 lbs/hr, height of release approximately 100 m (330 feet).

Time	Cylinder Weight (lbs)	Estimated Wind
0400	210.0	SE
0415	203.5	SE
0430	197.0	SE
0445	191.5	E
0500	185.0	ESE
0515	179.0	SE
0530	172.5	SE
0545	166.5	ESE
0600	160.0	ESE
0615	154.0	SE
0630	270.0	SE
0645	263.8	E
0700	258.0	ESE
0715	251.3	SE
0730	245.0	SE
0745	239.1	SE
0800	232.2	SSE
0815	226.0	SE
0830	220.0	SE
0845	213.5	SSE
0900	207.2	S
0915	201.5	S
0930	194.5	NE
0945	188.0	SSW
1000	182.0	SW
1015	176.5	SW
1030	170.2	SSW
1045	164.0	SSW

APPENDIX C

Tracer Gas Concentration Data

TABLE C-1. Observed automatic sample data (ppt), 14 September 1978.

Site	Hour				
	0600-0700	0700-0800	0800-0900	0900-1000	1000-1100
1	87	28	1	3	24
2	10	19	207	1,440	1,610
3	629	812	1,256	39	95
4	263	183	8	6	11
5	51	2	2	0	31
6	0	9	48	17	5
7	6	28	51	23	3
8	13	58	52	13	4
9	-	98	78	12	5
10	62	15	-	12	6
11	142	232	49	12	5
12	9	30	9	11	5
13	161	227	4	6	6
14	4	8	3	5	6
15	0	0	1	2	6
16	1,361	1,023	86	6	8
17	7	40	2	5	9
18	0	0	1	2	9
19	1	0	0	0	5
20	1	0	0	0	5
21	0	0	0	2	9
22	0	0	1	1	6
23	2	1	13	210	1,243

TABLE C-2. Observed grab sample data (ppt), 14 September 1978.

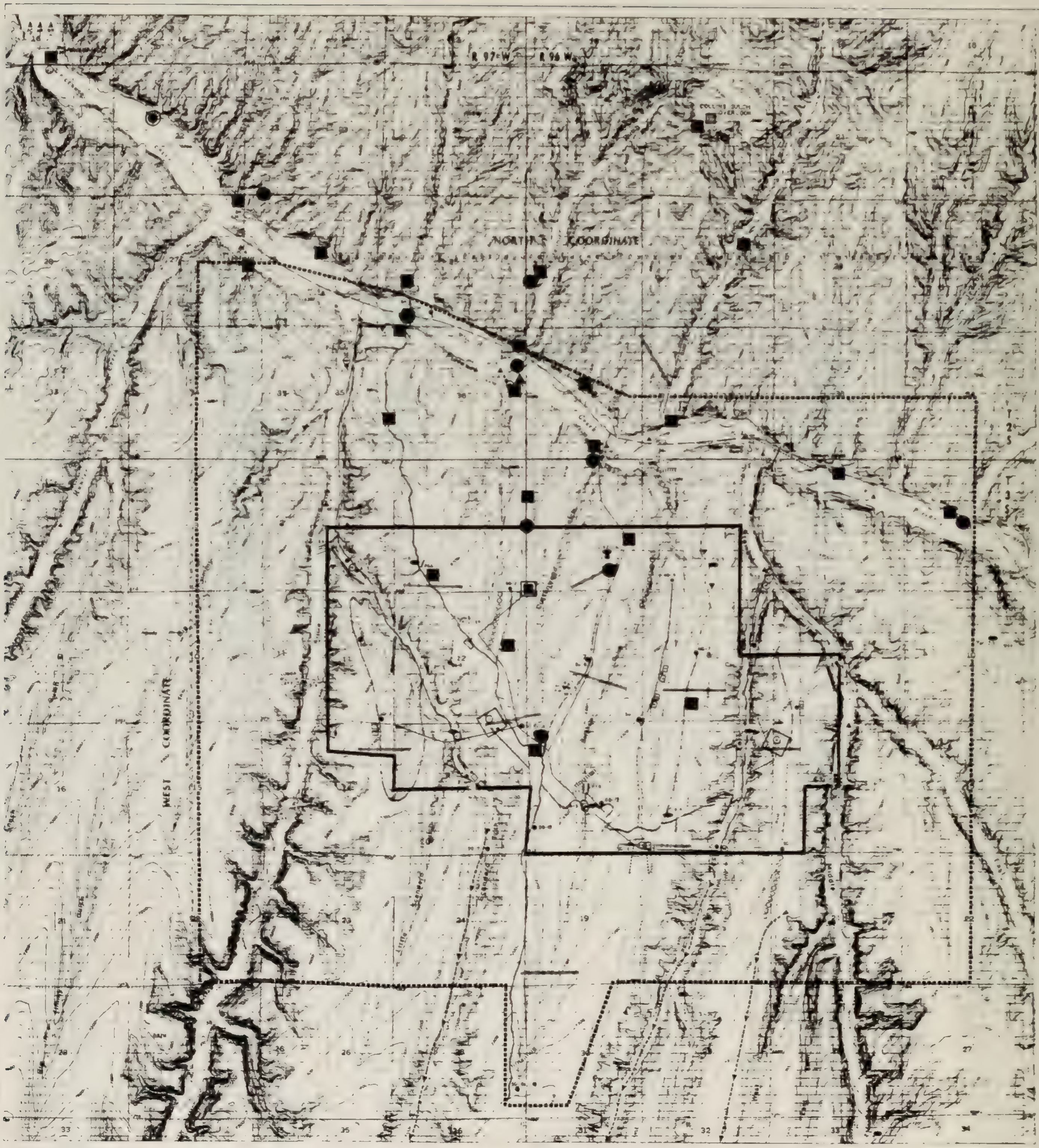
Site Number	Time	(ppt) Concentration	Site Number	Time	(ppt) Concentration
1	0600	376	32	0853	20
2	0610	115	33	0901	2647
3	0614	-	34	0903	8
4	0620	64	35	0906	2
5	0626	365	36	0912	2
6	0631	64	37	0915	2
7	0635	22	38	0922	1623
8	0638	8	39	0945	7
9	0640	9	40	1005	121
10	0643	2	41	1023	7
11	0646	6	42	1029	13
12	0726	30	43	1032	11
13	0730	82	44	1032	3244
14	0733	85	45	1035	9
15	0736	125	46	1037	8
16	0738	54	47	1040	8
17	0743	98	48	1040	216
18	0749	1	49	1043	6
19	0754	11	50	1046	5
20	0756	1	51	1048	13
21	0759	3	52	1051	5
22	0803	2	53	1052	14
23	0805	2	54	1053	4
24	0809	2	55	1058	10
25	0815	2	56	1102	4
26	0818	1	57	1108	3
27	0821	1	58	1113	6
28	0825	2	59	1116	7
29	0841	3	60	1119	6
30	0846	55	61	1122	8
31	0849	6			

TABLE C-3. Observed automatic sample data (ppt), 15 September 1978.

Site	Hour				
	0600-0700	0700-0800	0800-0900	0900-1000	1000-1100
1	1	0	0	0	3
2	1	1	3	180	2
3	82	63	26	385	0
4	1	1	1	157	85
5	0	0	0	1	0
6	2	1	1	28	8
7	3	2	2	28	11
8	2	0	1	28	15
9	0	1	1	25	2
10	3	1	2	129	2
11	1	1	2	109	3
12	0	0	1	81	3
13	1	0	0	49	28
14	1	0	0	54	39
15	1	1	1	61	-
16	1	1	0	30	14
17	1	0	1	131	58
18	1	1	2	22	45
19	0	0	0	21	31
20	0	1	1	52	59
21	2	0	1	0	1
22	0	0	1	0	1
23	0	1	1	1	1

TABLE C-4. Observed grab sample data (ppt), 15 September 1978.

Site Number	Time	(ppt) Concentration	Site Number	Time	(ppt) Concentration
1	0643	0	35	0935	2
2	0649	2	36	0939	1
3	0652	19	37	0942	5
4	0655	1	38	0945	17
5	0659	0	39	0948	32
6	0703	3	40	0951	31
7	0713	2	41	0958	20
8	0716	3	42	1000	1
9	0718	3	43	1002	39
10	0724	1	44	1003	1
11	0728	3	45	1005	1
12	0731	1	46	1006	1
13	0734	1	47	1008	1
14	0744	3	48	1010	15
15	0750	2	49	1010	1
16	0750	2	50	1013	1
17	0754	2	51	1013	1
18	0802	0	52	1026	1
19	0815	1	53	1032	1
20	0830	1	54	1035	1
21	0851	0	55	1045	0
22	0854	2	56	1047	1
23	0857	3	57	1050	1
24	0900	1	58	1051	1
25	0900	2	59	1053	34
26	0903	8	60	1104	1
27	0914	2	61	1111	1
28	0916	218	62	1113	0
29	0917	1	63	1118	0
30	0920	16	64	1121	0
31	0923	24	65	1124	2
32	0927	13	66	1127	1
33	0927	6	67	1130	0
34	0932	10			



SF_6 RELEASE SITE
AIR SAMPLING SITE (AS)
METEOROLOGICAL MONITORING SITE
ACOUSTIC SOUNDING SITE
TETHERSONDE MEASUREMENT SITE
AIR ANALYSIS FARMHOUSE

C.B. Diffusion Tracer Study
Monitoring and Release Sites.
September, 1978

APPENDIX 7.0

Validation of a Model for Simulating Dispersion in Complex Terrain

AV FR 8200

Final Report

VALIDATION OF A MODEL FOR SIMULATING DISPERSION IN COMPLEX TERRAIN

Prepared for

C-b Shale Oil Venture
2372 "G" Road
P.O. Box 2687
Grand Junction, Colorado 81501

November 1978

AEROVIRONMENT INC.
145 VISTA AVE. PASADENA, CALIFORNIA 91107
(213) 449-4392

AeroVironment Inc.
145 VISTA AVENUE · PASADENA, CALIFORNIA 91107 · U.S.A. · (213) 449-4392

25 April 1979

Dr. George Fosdick
Occidental Oil Shale Inc.
P.O. Box 2687
Grand Junction, CO 81501

Dear Dr. Fosdick:

Please find enclosed an explanation and format for the computer listing in the appendix of the C-b Validation Report. I hope you find this sufficiently clear in understanding the significance of the various inputs.

I have also enclosed copies of the references you requested. I will be happy to give any additional information that you may require.

Sincerely,

Savithri Machiraju

Savithri Machiraju
Atmospheric Scientist

SM:em

Enclosures

P.S. Due to an ongoing reorganization of our library, we couldn't find the report by Sklarew and Wilson at the moment. However, we are obtaining a copy from Ralph Sklarew which I shall send to you on Monday (4/30/79). I am enclosing the paper by MacCready et al (1974). I am sorry about this delay.

S.M.

FORMAT OF INPUTS TO AVMSTM

CARD NO.

1) Initialization Data; Format: Namelist "INIT":

Includes: Unit numbers for card reader and line printer (ICR, IPR)

Number of grid squares in x, y, and z directions (NX, NY, NZ)

Dimension (meters) of a single grid square in x, y, and z directions (DX, DY, DZ).

(Note that (NX·DX) (NY·DY) (NZ·DZ) gives the total volume under consideration in m^3).

Number of sites used for wind inputs (NOWDS) and stability inputs (NSTAB).

Total number of hours (or any other time unit) for which plume is being modeled (NHRS); total number of sources (NS) and receptors (NR).

Amount of rotation, if any, of the grid axis with respect to the geographical N-S axis (DEG).

Program option to model plume (IWND).

2) Format: 6F10.3, 2I5

Includes (in order): time step used to calculate plume segments, x, y, and z - origin of grid in meters, four options of the program.

3) Format: 16I5

Includes: Terrain information for each grid square, column by column. This terrain value multiplied by DZ and added to the z-origin of the grid gives the elevation of that grid square in meters.

4) Wind Inputs: Format 3F10.2

For each hour, we have the following set-up:

(i) x and y coordinates of wind site (m), confidence level assigned to wind inputs (0.0 ⟶ 1.0).

(ii) ⟶ (xi) wind speed (mph), wind direction, temperature, at each level of elevation.

cards (i) through (xi) are repeated for each wind site. Since we have 5 wind sites here, this results in a total of 55 cards for each hour .

5) Stability Input: Format 2F 10.2, 60I1:

x & y coordinates of stability site, followed by stability assigned to each level of height i DX, i = 1, NZ, starting from the ground level. One card for each stability site per hour. Since we have two stability sites, we have two cards for each hour.

6) Source input: Format: 8F10.2

Includes: source x & y coordinates (m), source emission rate (gm/sec), stack height (m), stack diameter (m), exit temperature of stack (^{o}K), exit velocity (m/sec), and volume flow (m^3/sec).

7) Receptor input: Format: 2F10.2

Includes: x & y coordinates of receptors (m.).

AV FR 8200

Final Report

VALIDATION OF A MODEL FOR SIMULATING DISPERSION IN COMPLEX TERRAIN

Prepared for

C-b Shale Oil Venture
2372 "G" Road
P.O. Box 2687
Grand Junction, Colorado 81501

By

Michael W. Chan, Sara J. Head, and Savithri Machiraju

AeroVironment Inc.
145 Vista Avenue
Pasadena, California 91107

November 1978

SUMMARY

This report describes the validation of a computer program - AVMSTM - that simulates the dispersion of pollution in complex terrain. AVMSTM logically treats wind field, plume transport, and turbulence in complex terrain. Validation results show that good agreement exists between observed and predicted concentrations under a wide range of meteorological conditions.

TABLE OF CONTENTS

1. INTRODUCTION

According to the Clean Air Act Amendments of 1977 (U.S. Congress, 1977), any development in areas where ambient air quality standards are presently maintained has to undergo a significant air quality deterioration evaluation, and such an evaluation must utilize air quality models specified by the Environmental Protection Agency in the Guideline on Air Quality Models (U.S. EPA, 1978).

However, the Guideline does not have any recommendations on models to be used in complex terrain. Instead, it suggests that expert advice be employed in such circumstances. Thus, to assist the C-b Shale Oil Venture in securing an air quality permit for a proposed ancillary facility consisting of two or more commercial-sized retorts on Federal Oil Shale Lease Tract C-b, which is located in complex terrain, AeroVironment plans to use its complex terrain model, AVMSTM.

To ensure that the AVMSTM model is applicable to the C-b tract environment, a model validation experiment was performed in September 1978. A description of the experiment and a presentation of the data collected during that experiment are given in a report by Chan and Smith (1978).

This report gives a description of the complex terrain model, AVMSTM, and discusses the results of the model validation exercise.

2. DESCRIPTION OF THE MODEL FOR SIMULATING DISPERSION IN COMPLEX TERRAIN - AVMSTM

Air pollutant concentrations at a receptor resulting from a point release are functions of both airflow pattern and turbulent dispersion within this flow. For the simple case of planar terrain, streamlines are well-defined and the assumption of a uniform wind field is not unrealistic. For such a simple case, dispersion properties have been the subject of considerable theoretical and experimental research and are now fairly well-defined in a quantitative fashion. The effect of topographic roughness, adds, on the one hand, an enhancement of the diffusion because of increased mechanical turbulence and wind shear, which is counterbalanced by a possibility of greater pollutant concentrations on rising terrain. In such non-planar terrain the flow trajectories are convoluted by topographic channeling and by thermally induced flows. A model has been developed that rationally determines wind field, defines plume transport, and simulates dispersion of pollutants in complex terrain. A description of this model - AVMSTM - follows.

2.1 General Model Capabilities

AVMSTM is a broad purpose Gaussian plume model which is able to model transport and diffusion in a spatially inhomogeneous, temporally unsteady wind field in rough terrain. It contains submodels within it for the estimation of wind fields, for the computation of plume rise, for the definition of plume transport, and for the determination of surface-roughness related diffusion. The program is capable of accepting a large number of sources and receptors over micro- or regional scales.

The wind field is defined by a three-dimensional numerical interpolation and extrapolation of measured winds in such a way as to eliminate divergences, satisfy topographic boundary conditions, and respond to atmospheric stability effects. The general methodology is adapted from the work of Sklarew and Wilson (1976). This technique does not explicitly model thermally-driven flows, but will model them rationally in the presence of some measured data. In addition to the general wind field model, specialized routines can be inserted to handle such effects as separated flows over extreme topographic elements. For example, flow over a cliff was treated by Mullen, et al (1977a).

Plume rise calculations are based on the formulations of Briggs (1971) and revised by Turner (1973). Meteorological data required for these calculations are those generated by the wind field submodel.

Plume transport is treated by segmenting the plume centerline (at any given time into any time increment. This pseudo-steady-state, pseudo-puff treatment allows the plume to follow spatial and temporal changes in the wind field within the temporal resolution of the given wind data. Since a three-dimensional wind field is defined by the wind field submodel, the vertical location of the plume centerline is continuously defined.

Plume dispersion is calculated using the widely accepted Gaussian plume equation (Gifford, 1960). The program is modularized to readily accept a variety of subprograms for calculating the horizontal and vertical standard deviations of plume width (sigmas) used in the Gaussian equation, depending on the meteorological data available and the type of terrain. The AVMSTM model discussed here calculates complex terrain sigmas which employ algorithms developed by AeroVironment. These algorithms utilize measured fluctuations of wind direction and wind meander, and empirical formulations derived from the Lo-Low Altitude Clear Air Turbulence Project (LO-LOCAT) to account for the roughness of the terrain, as described by MacCready, et al (1974).

2.2 Wind Field Submodel

The basic concept in this submodel are adapted from the work of Sklarew and Wilson (1976). This submodel first assigns a stability to each grid cell of a three-dimensional grid system defined by the user. This assignment is accomplished by interpolation of input stability data via a $1/r^4$ weighting factor.

The submodel then develops wind flow in the three-dimension grid from all input wind data, topographic data, as well as the calculated stability data. The winds calculated are consistent with any terrain resolved in the three-dimensional grid as well as completely divergence-free.

This wind field development starts with projecting wind data upwards from the point of observation through the portion of the grid without any measurements based on a vertical power law profile of the form

$$u = u_o \ (Z/Z_o)^P$$

for speeds u, and u_o at vertical coordinates Z and Z_o, respectively, with P determined from the following table:

Stability Category	A	B	C	D	E	F	G
P	.15	.17	.20	.26	.39	.48	.54

After the wind speeds are projected upwards, the wind speed and direction are resolved into U and V vector components at every wind site. Then, the entire wind field is developed via a weighted $1/r^2$ interpolation of the vertical profiles for each horizontal plane. Up to this point, terrain has not been considered. Terrain first enters into the wind field determination by shifting the interpolated winds upward to clear the terrain. Following this, the wind fluxes in and out of the boundaries of the computational domain are adjusted such that the flux in equals the flux out.

Atmospheric stability has the effect of varying the relative response to terrain of horizontal and vertical motion. For a neutral or unstable air mass, the flow tends to pass directly over an obstacle, without significant lateral diversion. For a stable airflow, gravitational effects tend to restrict an air parcel from flowing over an obstacle and direct the airstream around the obstacle. This phenomenon is incorporated into the model by assigning transparencies of the horizontal and vertical cell faces based on stability.

The nondivergence of the wind field is imposed by interactive solution based on calculating the divergence such that

$$\nabla \cdot U = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = D$$

and readjusting the velocity to minimize the divergence. A finite difference, iterative scheme is used in the computation. At the completion of the iterative cycle, all residual divergences are swept out of the top of the grid. This completes the generation of a three-dimensional wind for each cell of the grid system.

2.3 Plume Transport Submodel

For a continuously emitting point source, a trajectory of the plume can be defined, in principle, and is defined in the plume transport submodel by the streak line* of the air flow passing over the source. Once the streak line of the plume is defined, it is broken up into segments. Each segment is represented by a tube with a Gaussian cross-section in the horizontal and vertical direction. The length of each tube is defined by the emissions produced by the source in the time increment of interest (usually from 15 minutes to one hour), and remains constant for the life of the segment. Each successive segment of the plume is a time increment older than the preceeding segment if observed by moving downwind along the streak line away from the release point. Each plume segment has a history and has been subjected to aging, various wind speeds, stability classes, terrain roughness, and distance traveleo. The history of the plume and its present state are defined by the plume cross-section which is assumed to have a bivariate Gaussian distribution. The cross-section of this distribution is defined by complex terrain algorithms (sigmas) as summarized in the next section, and is updated each hour.

Since this approach is somewhat unusual two examples will help to illustrate this pseudo-steady-state, pseudo-puff concept. First, say that the wind in the study area is uniform spatially, but has erratically shifted from a northwesterly direction to a southwesterly flow in a five-hour period as shown in Figure 2-1a. The idealized representation of a plan view of the streak line of the plume consisting of hourly plume segments emitted since time t - 4, or five hours ago, is shown in Figure 2-1b. This is how the plume would appear at time t. An hour later, at time t + 1, the plume would appear as in Figure 2-1c.

Consider the plume segment between station 3 and station 4 initially at time t. The cross-section of this tube can be completely described if it is assumed to be Gaussian and the σ_y and σ_z are known at every x along the streak line between 3 and 4. An hour later

---

* A streak line is defined by connecting, in sequence, all elements of air passing over a point, i.e., the source.

FIGURE 2-1a. Wind vectors from time t-4 to time t + 1.

FIGURE 2-1b. Streak line and plume boundaries at time t.

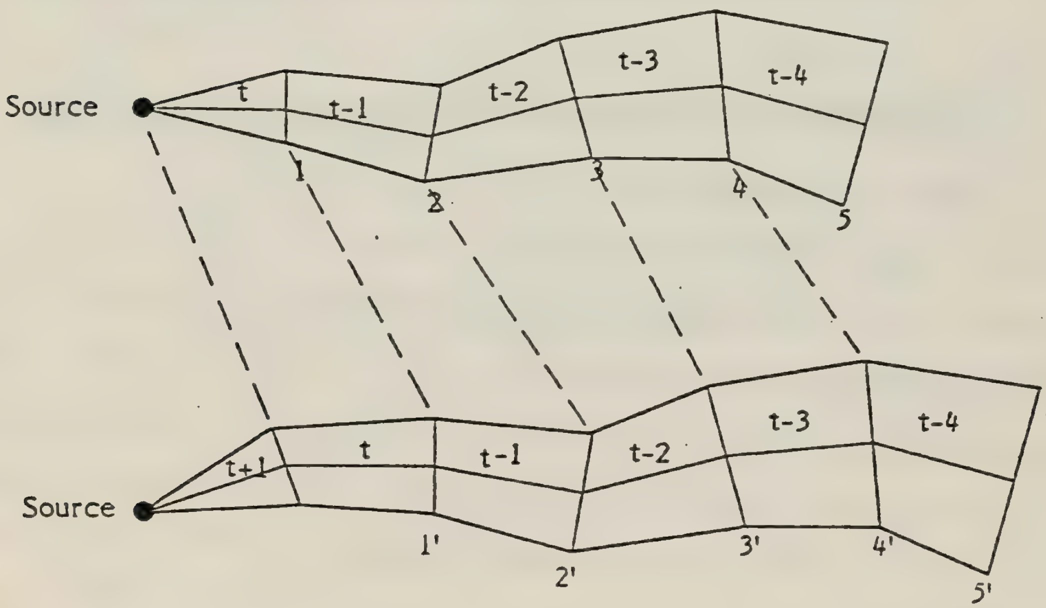


FIGURE 2-1c. Streak line and plume boundaries at time t + 1.

at time $t + \Delta t$, station 3 has moved to 3' and station 4 has moved to 4'. The plume cross-section σ (σ_y or σ_z) changes when moving from 3 to 3' according to the expression

$$\sigma_3' = \sigma_3 + \frac{d\sigma}{dt} \Delta t$$

which can be rewritten

$$\sigma_3' = \sigma_3 + \left.\frac{\partial \sigma}{\partial x}\right|_3 u \Delta t + \left.\frac{\partial \sigma}{\partial t}\right|_t \Delta t$$

where u is the wind speed representative of the hour t to $t + \Delta t$

$\frac{\partial \sigma}{\partial x}$ represents the spatial variation of σ

$\frac{\partial \sigma}{\partial t}$ represents the temporal variation.

Because of the pseudo-steady-state assumption, $\frac{\partial \sigma}{\partial t}$ is zero during the interval from t to Δt. The derivatives of σ_y and σ_z with respect to x can easily be evaluated by differentiating the σ equations discussed in the next section, thus allowing calculation of σ'.

Concentrations are then calculated by the standard Gaussian plume formulas.

Consider now a non-homogeneous wind field, i.e., one with turning flow. Figure 2-2a shows a streamline* passing over a source, with wind vectors at coordinate points S_0, S_1, and S_2. The pseudo-steady-state approach assumes that this streamline would be invariant within a selected time increment, say, one hour. As before, the plume generated during that hour can be simulated by a segment as shown in Figure 2-2b where the centerline of the plume is defined by the vector $\overrightarrow{U}(S_0, t) \Delta t$. If this length is small compared to the radius of curvature of the streamline, then the segment will accurately follow the streamline. If this is not the case, and finer time-scale wind data is available, then a better fit is achieved by using a smaller time interval Δt.

---

* In contrast to a streak line, a streamline at any moment is defined by the velocity vectors in the flow. The flow is parallel to the streamlines. It does not define the flow trajectory, except in steady flow.

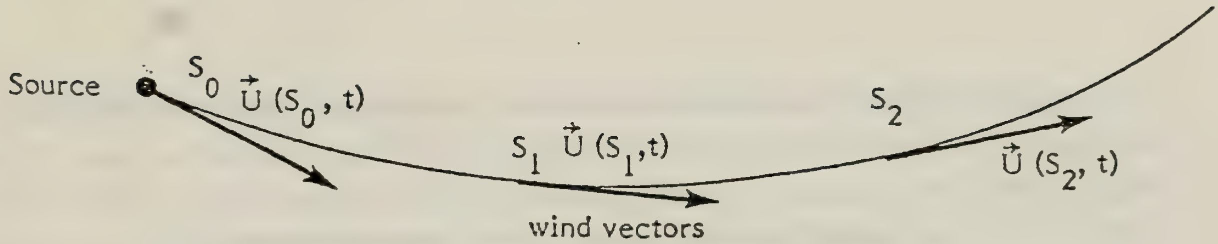


FIGURE 2-2a. A steady-state stream line at time t.

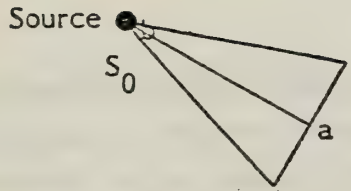


FIGURE 2-2b. Plume generated along this stream line starting at time t.

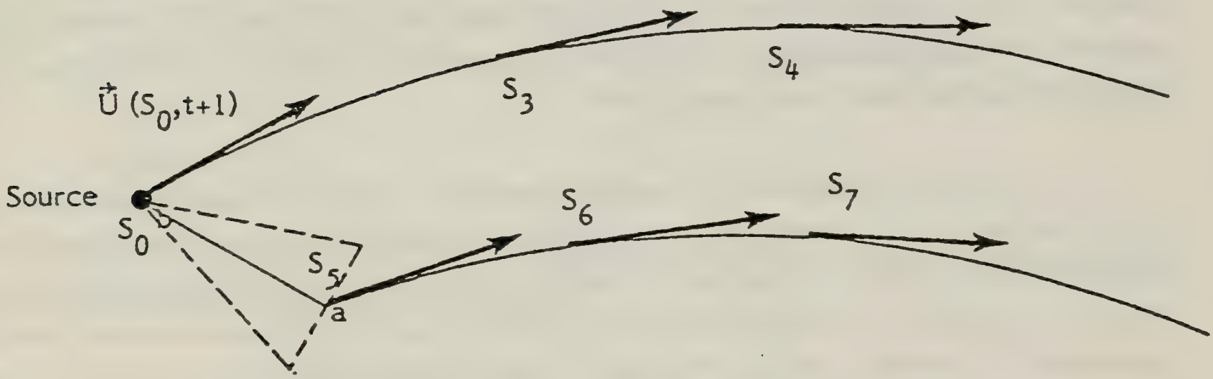


FIGURE 2-2c. Stream lines at time t + a.

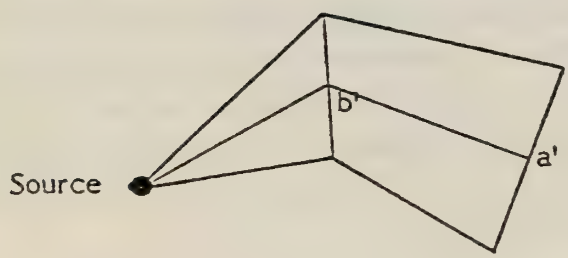


FIGURE 2-2d. Plume generated starting at time t plus transport of earlier plume segment by wind between S_0 and S_5.

At time t + 1 the wind field may be different than before, say as in Figure 2-2c. In that figure, S_5 is the coordinate location representing the flow to which the front of the initial plume is now subjected. After one hour the result is as shown in Figure 2-2d, where a new plume segment has been generated with length and direction $\vec{U}(S_0, t + 1)\Delta t$ and the ends a and b of the prior segment have been transported by an amount $\vec{U}(S_5, t + 1)\Delta t$ and $\vec{U}(S_0, t + 1)\Delta t$, respectively, to reach the locations a' and b'.

2.4 Diffusion Algorithms

The AVMSTM has a set of diffusion coefficients for complex terrain that relates the diffusion with the measured terrain roughness (σ_{tr}) and with the measured or predicted fluctuation (σ_θ) and meander (Δ_θ) of the wind. A detailed discussion of the derivation of these coefficients appears in a paper by Mullen, et al (1977b). The diffusion algorithms generated were designed to accept measured fluctuation and meander data but are general enough to operate with estimates of fluctuations based on standard stability classifications, as in AEC Guide 23 (AEC, 1972), if measured data are not available or better correspondence between observed and predicted concentrations can thus be obtained. The terrain roughness (σ_{tr}) is determined from USGS maps of the terrain using a simple technique developed by AV for the utilization of LO-LOCAT turbulence data for diffusion modeling (MacCready, et al, 1974).

The diffusion algorithms are modified versions of formulae suggested by Briggs (1974) for open country conditions. The Briggs formulae are functions of distance and Pasquill stability class. Calculations of diffusion coefficients based on a discrete set of stability categories do not necessarily bear a direct relation to actual turbulence levels, particularly in complex terrain. Therefore, in the AVMSTM model, diffusion coefficients are constructed based on the measured value of σ_θ (the r.m.s. wind vane fluctuations), which is a continuous and directly related function of the turbulence. The Briggs functional dependence with distance was approximately retained in these modified expressions, but the Briggs family of equations were replaced by a single equation that is a function of σ_θ and uses it as a scaling factor to regenerate the family of dispersion curves. The horizontal dispersion equation was further modified to account for the effective increase in horizontal dispersion due to the meander of the wind, when meander data are available, and the vertical dispersion equation includes enhancement of the vertical component of the turbulence by terrain roughness.

The resulting σ_y and σ_z (horizontal and vertical dispersion coefficients) are defined as:

$$\sigma_y = 0.009\, x \left(\sigma_\theta^{\;2} + \Delta_\theta^{\;2}\right)^{0.5} (1 + 0.0003\, x)^{0.5}$$

and under stability classes A through E:

$$\sigma_z = H_m + 0.45\, \sigma_{tr}^{\;0.13}\, u^{-0.475}\, \sigma_\theta\, x^{0.5}\, (1 + 0.0003\, x)^{k}$$

where $k = 0.86 - e^{-0.03\sigma_\theta}$

whereas, under stability Class F or G:

$$\sigma_z = H_m + 0.46\, \sigma_{tr}^{\;0.21}\, u^{-0.39}\, \sigma_\theta\, x^{0.5}\, (1 + 0.0003\, x)^{p}$$

where $p = 0.928 - e^{-0.03\sigma_\theta}$

Here, x is the downwind distance, u the wind speed, and H_m the initial plume speed. The rest of the symbols have previously been defined.

An approximation for H_m has been empirically derived by examining plume photographs and is equal to 10% of the plume rise at any x.

3. VALIDATION OF AVMSTM

The diffusion algorithm portion of AVMSTM was validated in 1977 using data collected in hilly terrain. Results of such validation are presented in a paper by Mullen, et al (1977b). The wind field submodel has also been validated. Validation results are discussed by Sklarew and Wilson (1976).

The validation experiment performed in September 1978 was designed to evaluate the overall performance of the model, namely, the capability of the model to predict correctly the spatial distribution of pollutant concentrations in complex terrain. If a good correlation exists between model predictions and observations, the plume transport submodel will also be validated. More importantly, a good correlation would mean that the model is well-suited for the assessment of impacts of the proposed development by the C-b Shale Oil Venture on Tract C-b.

To follow through this chapter, one has to read the report on the experiment (Chan and Smith, 1978), which is included here by reference.

3.1 Validation Procedure

The AVMSTM model requires a significant amount of computer core. Thus, an optimal number of grid cells, meteorological data sites, and receptor locations has to be predetermined. For the validation, a 10 x 10 x 10 grid system, five wind sites and nineteen receptors, were used. The grid system is needed only for the wind field determination. Concentrations can be predicted at any locatioin where the exact coordinates are specified.

The x, y plane of the grid system is shown in Figure 3-1. Each cell has a width of 800 m. The depth of a cell is 30 m. Elevation of each grid was specified for the model. The grid system was designed to orient the Piceance Creek along a row of grid cells as well as to include most of the receptors. As shown in Figure 3-1, receptor sites 6, 8, 20, and 22 are outside the grid boundary. Measurements at those locations showed insignificant amounts of SF_6. Predictions at receptors along the north, east, and west boundaries, as discussed later, also showed insignificant concentrations. Thus, inclusion of

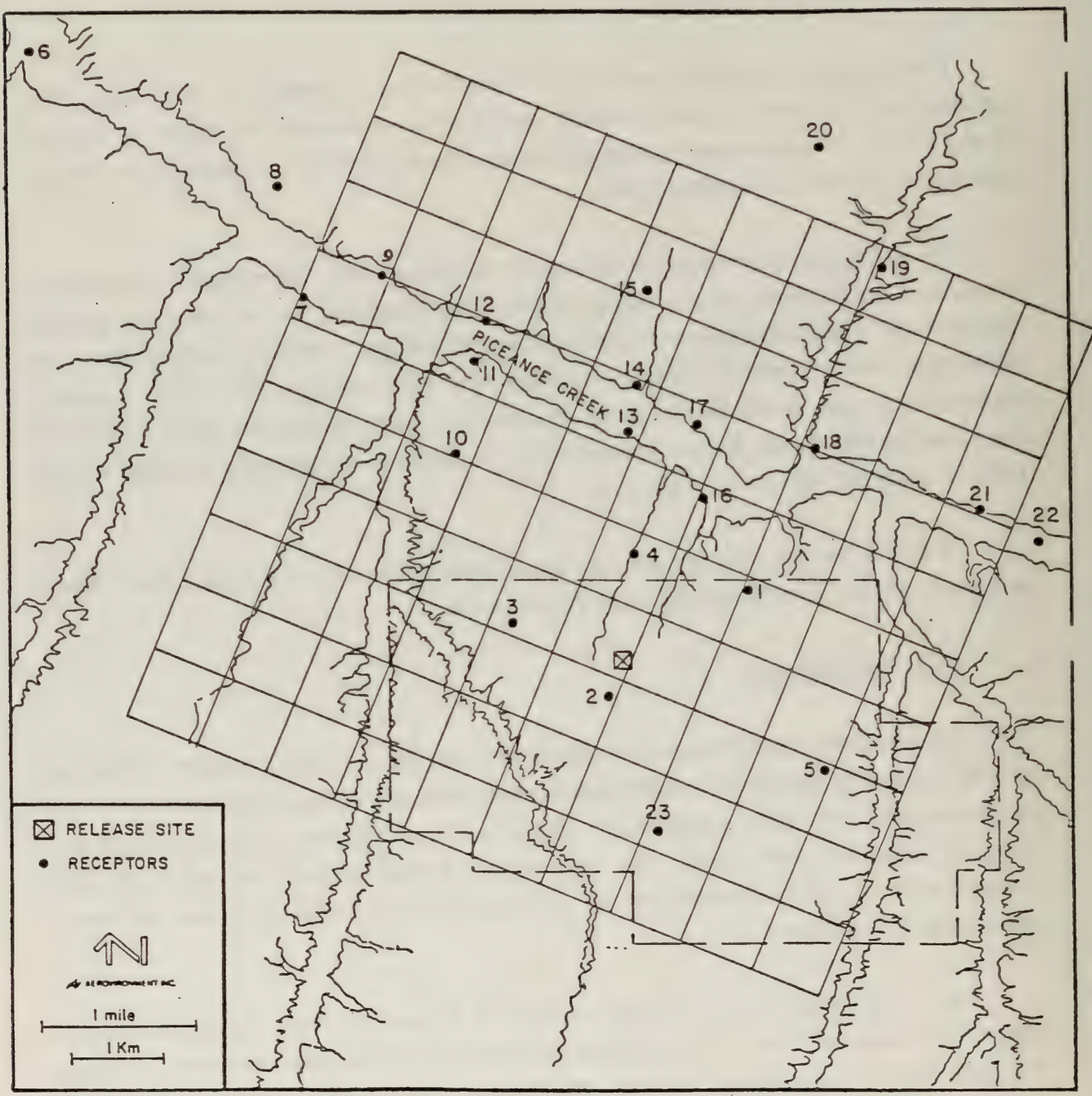


FIGURE 3-1. Grid system used in modeling.

those sites would only improve the correlation between predictions and observations. Exclusion of those locations would increase the difficulty of validation of the model and thus increase the credibility of the applicability of this model if a good correlation can still be obtained.

Quite a bit of wind shifts occurred during each hour of the experiment, as evidenced by the spatial distribution of SF_6 concentrations, presented in Figures 3-13 through 3-22 of the report by Chan and Smith (1978). In order for the model to be able to simulate such wind shifts, plume streak lines were computed at 15-minute intervals. Wind observations for each 15-minute interval were used to generate the entire wind field. Measured data at meteorological sites 022, 023, 045, and 048 (see Figure 2-9 of report on experiment) were used. In addition, wind data at the source was also used as an input to the model. The wind at the source was estimated based on the observation of the orientation of the kytoon as well as measurements at meteorological sites 020, 024, 042, and 056.

The input data are too voluminous to tabulate in the text. They are presented instead in Appendix A.

For each of the two days of experiment, simulation by AVMSTM of SF_6 release was initiated at 0500 MDT, an hour before ground level SF_6 concentration data were available. This allowed the plume to establish itself, simulating a quasi-steady state situation. The AVMSTM was run continually through 1100 MDT. Outputs of the model are discussed in the next section.

3.2 Validation Results

In an air quality impact assessment, modeling of the impact from a development is usually performed for the worst-case situation. The objective is to determine if such a development would cause exceedances of any standards or maximum allowable increments. Emphasis is placed on being able to predict, as accurately as possible, high concentrations. A good model should thus be one that is capable of giving reasonably accurate answers under conditions conducive to high pollution. Even if such a model misses predictions of low concentrations, it should still be considered applicable for use in the impact assessment. This should be kept in mind in evaluating the results presented in this section.

One of the special features of AVMSTM is its ability to track a plume. Figure 3-2 shows the plume streak lines for each 15-minute interval during 0600 MDT on 14 September 1978 as predicted by the model. For the first half hour, the plume drained down to Piceance Creek then turned and flowed along the Creek. For the last half hour, the plume was predicted to rotate in a counterclockwise direction from going toward the north-northeast to going toward the west. During this time period, the plume still followed the terrain down into and then flowed along the Creek. This unique ability is a major contribution to the success of the model in predicting the spatial distribution of concentrations.

Table 3-1 presents a comparison of predicted versus observed SF_6 concentrations, showing a good correspondence between observed and predicted values.

The overall performance of the AVMSTM for the two days of simulation is indicated by the linear regression plot of observed versus predicted concentrations in Figure 3-3. The correlation coefficient was 0.91. The intercept was 0.01 and the slope was 0.87. Such a good fit indicated that the model was able to predict reasonably well the spatial as well as temporal variability of pollutant concentrations under various meteorological conditions.

To test how well the model predicted the spatial distribution for each hour of the experiment, regressions of data sets for each hour were made. Table 3-2 presents the correlation coefficients, intercepts, and slopes. Good correlations were obtained for all hours. All intercepts were less than 0.5, an artifact due to the large numbers of low values, both in the predicted and observed concentrations. The slope gives a better indication on how closely the predictions were to the observations. There was only one hour, where the predictions were about 12% lower than observations. One hour had a slope of 1.00. Six hours had slopes between .75 and .95, indicating that the model was overpredicting by about 5% to 25%. The remaining two hours showed overpredictions of a factor of two and five. However, the very high overpredictions (a factor of five) occurred in the hour when none of the observations were higher than .55 $\mu g/m^3$. As pointed out earlier, the most important merit of a model is to be able to predict accurately when the concentrations are high, which was what the AVMSTM showed it could do.

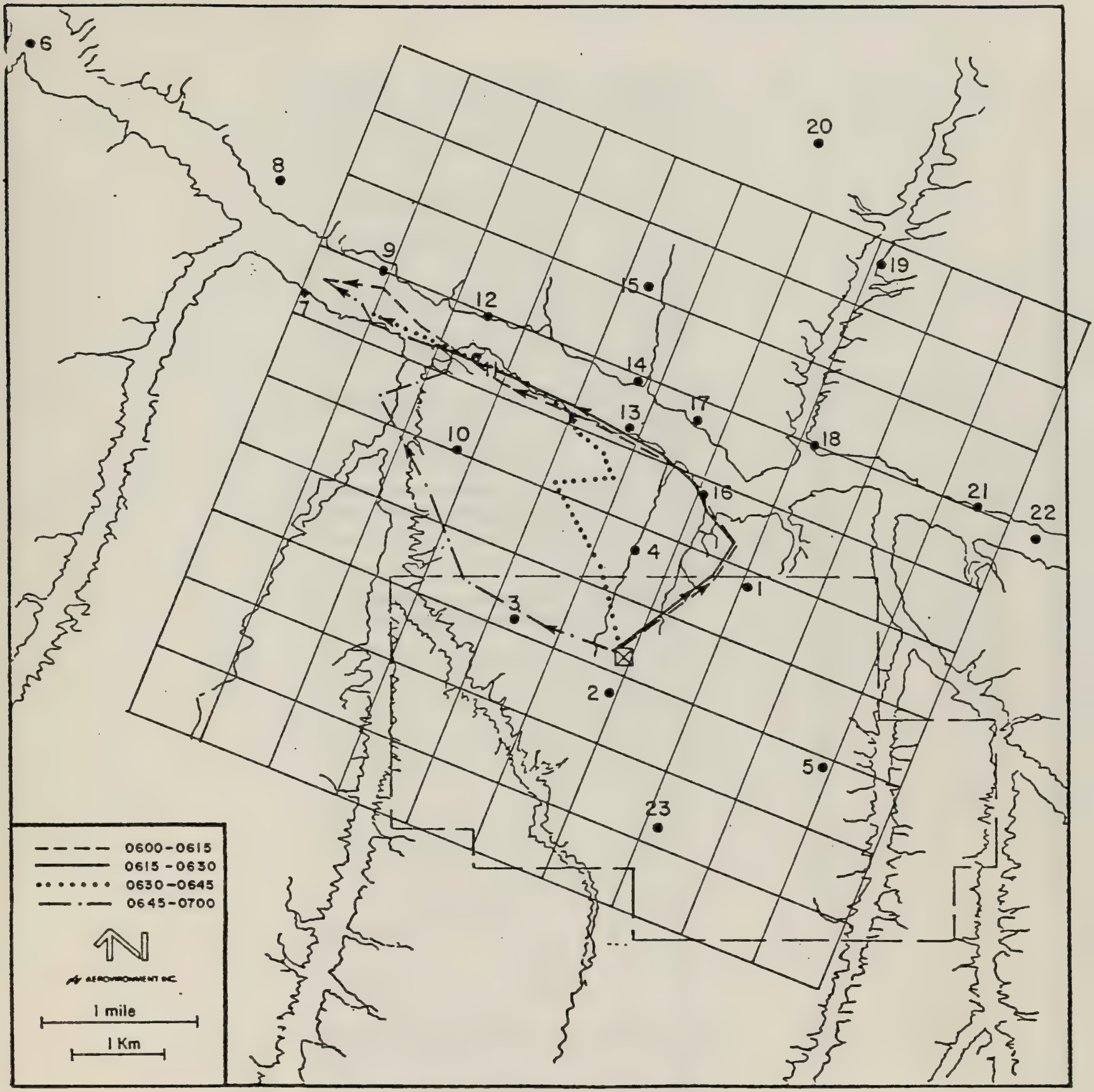


FIGURE 3-2. Streak lines of the SF_6 plume predicted by AVMSTM for 0600 MDT, 14 September 1978.

TABLE 3-1. Predicted versus Observed SF_6 Concentration ($\mu g/m^3$).

	0600-0700		0700-0800		0800-0900		0900-1000		1000-1100	
	9/14/78									
Site	P*	O	P	O	P	O	P	O	P	O
1	0	.32	0	.17	0	.01	0	.02	.24	.14
2	0	.06	0	.11	0	1.23	10.60	8.59	11.88	9.60
3	3.38	3.75	4.78	4.84	6.57	7.49	.52	.23	.02	.57
4	2.22	1.57	.69	1.09	0	.05	0	.04	0	.07
5	0	.30	0	.01	0	.01	0	0	.50	.18
7	.92	.04	.83	.17	.25	.30	.04	.14	0	.02
9	1.70	-	.79	.58	.60	.47	.03	.07	0	.03
10	1.09	.37	.64	.09	2.93	-	0	.07	0	.04
11	3.00	.85	.39	1.38	1.00	.29	0	.07	0	.03
12	2.00	.05	.50	.18	1.46	.05	.01	.07	0	.03
13	3.58	.96	1.20	1.35	1.43	.02	0	.04	0	.04
14	1.00	.02	.75	.05	1.94	.02	0	.03	0	.04
15	0	0	0	0	0	.01	0	.01	0	.04
16	7.29	8.12	4.78	6.10	1.41	.51	0	.04	0	.05
17	.39	.04	1.27	.24	.57	.01	0	.03	0	.05
18	0	0	0	0	0	.01	0	0	0	.05
19	0	.01	0	0	0	0	0	0	0	.03
21	0	0	0	0	0	0	0	.01	0	.05
23	0	.01	0	.01	0	.08	.22	1.24	3.03	7.42

	0600-0700		0700-0800		0800-0900		0900-1000		1000-1100	
	9/15/78									
Site	P	O	P	O	P	O	P	O	P	O
1	0	.01	0	0	0	0	0	0	.44	.02
2	0	.01	0	.01	0	.02	.11	1.10	.07	.01
3	.50	.49	.49	.38	.20	.16	3.76	2.30	0	0
4	0	.01	0	.01	0	.01	2.14	.94	1.90	.51
5	0	0	0	0	0	0	0	.01	0	0
7	0	.02	0	.01	0	.01	0	.17	0	.07
9	0	0	0	.01	0	.01	0	.15	0	.01
10	0	.02	0	.01	0	.01	.22	.77	0	.01
11	0	.01	0	.01	0	.01	0	.65	0	.02
12	0	0	0	0	0	.01	0	.48	0	.02
13	0	.01	0	0	0	0	0	.29	.31	.17
14	0	.01	0	0	0	0	0	.32	.07	.23
15	0	.01	0	.01	0	.01	0	.36	.24	0
16	0	.01	0	.01	0	0	0	.18	.95	.08
17	0	0	0	0	0	.01	0	.78	.14	.35
18	0	.01	0	.01	0	.01	0	.13	.81	.27
19	0	0	0	0	0	0	0	.13	.37	.18
21	0	.01	0	0	0	.01	0	0	0	.01
23	0	0	0	.01	0	.01	0	.01	0	.01

*P - Predicted values
O - Observed values

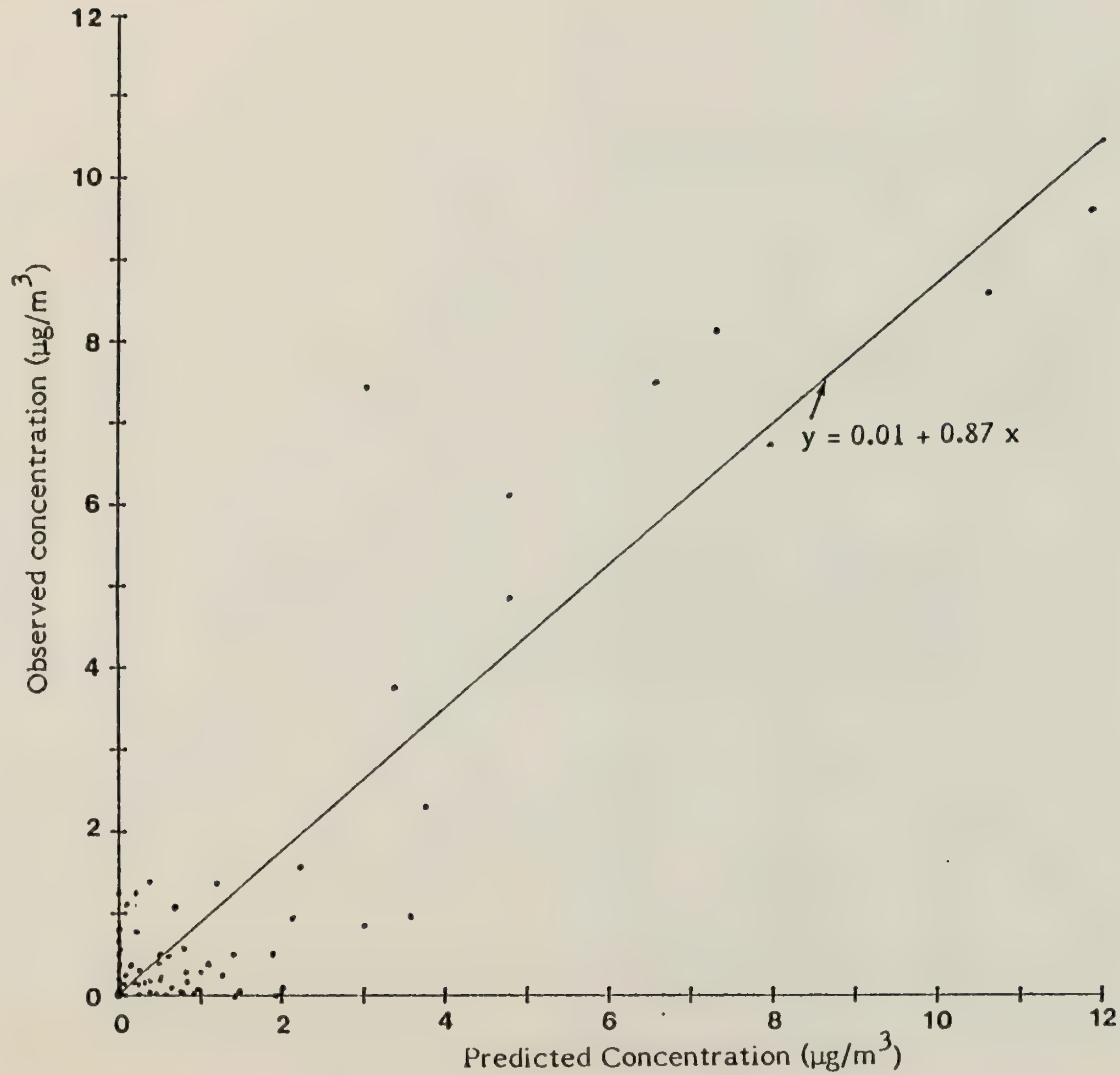


FIGURE 3-3. A linear regression plot of observed versus predicted concentrations.

TABLE 3-2. Linear regression results for individual hours of predictions versus observations.

Date	Time MDT	Correlation Coefficient	Intercept	Slope
9/14/78	0600-0700	.88	-0.34	.92
	0700-0800	.95	-0.12	1.12
	0800-0900	.89	-0.26	1.00
	0900-1000	.99	0.08	.80
	1000-1100	.91	0.25	.88
9/15/78	0600-0700	1.00	.01	.76
	0700-0800	.99	.01	.76
	0800-0900	.99	.01	.76
	0900-1000	.83	.30	.48
	1000-1100	.72	.04	.22

The ability of the model to predict the temporal variations of SF_6 concentrations is illustrated in Figure 3-4. Sites 2, 3, and 16 were selected because they were the only sites with observed concentrations greater than 1.5 $\mu g/m^3$. The ability of the model to track the temporal variability of the SF_6 concentrations at affected receptors is obvious.

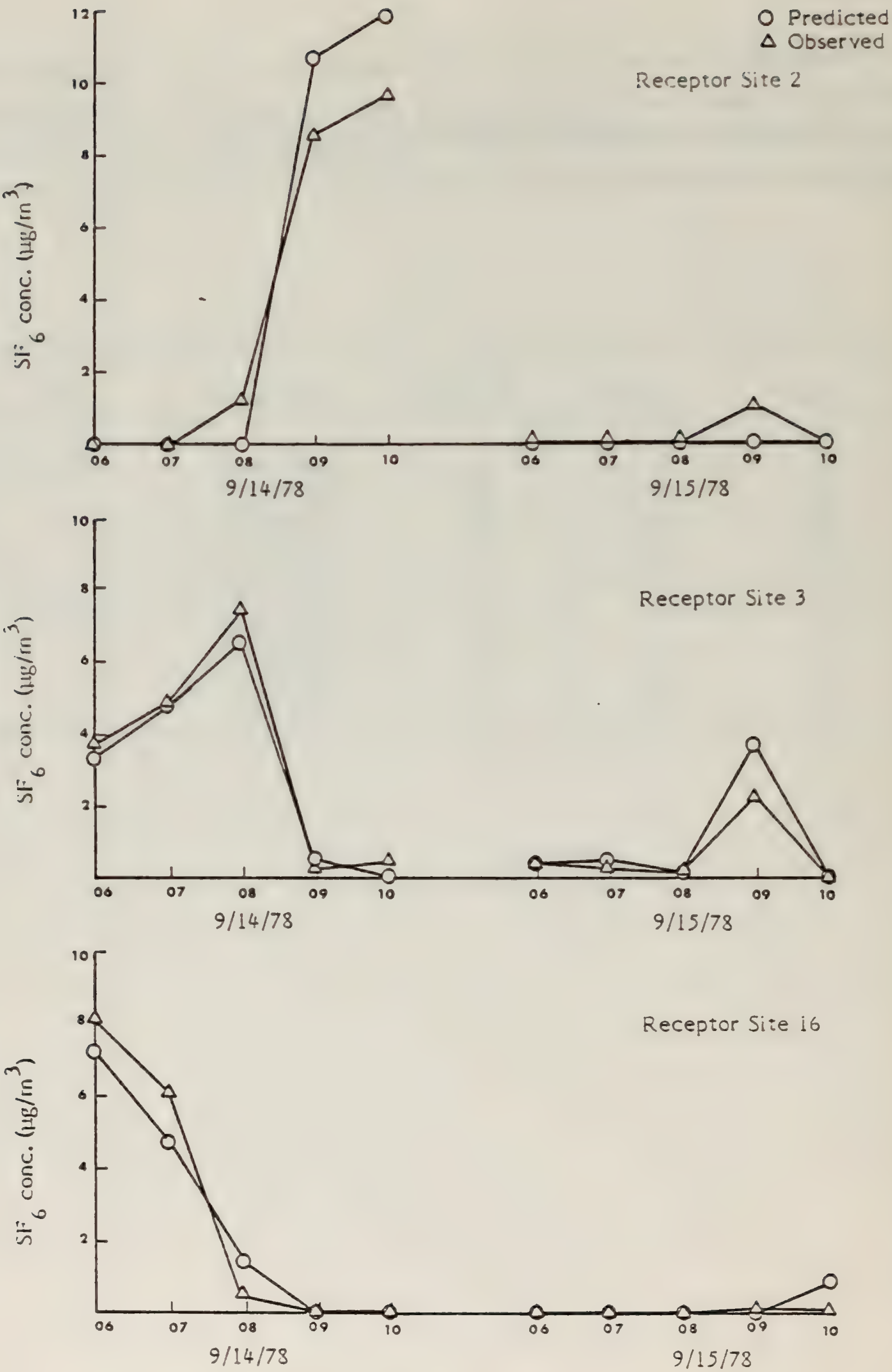


FIGURE 3-4. Trend analysis of predicted and observed SF_6 concentration at Sites 2, 3, and 16.

4. CONCLUSIONS

A wide spectrum of meteorological conditions were observed on the tract during the experiment. Stability conditions varied from Class D to Class F, wind speeds ranged from less than 1 m/s to over 10 m/s, and wind directions covered all cadrinal points. Yet, the model was able predict reasonably well for the whole period of the experiment. In fact, the correlation coefficient between observed and predicted SF_6 concentrations was 0.91. This is a good indication that AVMSTM is applicable for assessing impacts from activities on Tract C-b under all meteorological conditions (or, at least, when the atmosphere is neutral or stable). The slope of the linear regression was 0.87. This implies that using AVMSTM without any calibration factors would result in overpredictions in the average of about 13%.

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APPENDIX A

Listings of Inputs to AVMSTM

Listings of Inputs for Day 1

14 September 1978

```
$INIT ICR=5,IPR=6,NX=10,NY=10,NZ=10,DX=800.,DY=800.,DZ=030.,NOWDS=5,NSTAB=2,
NHRS=24,NS=1,NR=19,IWND=1,DEG=23. $END
450.     0.0      0.0      1900.     0.0      1.0           1    1
    5    4    3    3    2    1    0    1    3    4    5    4    3    2    2    1
    0    2    4    6    5    4    2    2    1    0    0    2    3    6    3    2
    2    3    3    2    0    4    5    7    5    4    3    4    3    2    0    3
    4    5    6    5    4    4    3    2    1    4    6    8    6    5    5    4
    3    1    1    3    4    5    6    5    5    5    4    3    1    3    5    6
    7    6    6    5    4    3    2    4    6    7    7    6    5    4    3    3
    2    4    6    8
4640.    2720.    0.9
4.3      225.     -2.1
4.0      225.     -2.1
4.0      225.     -2.1
3.6      225.     -2.1
3.1      225.     -2.1
2.7      225.     -2.1
2.7      225.     -2.1
2.7      225.     -2.1
2.7      225.     -2.1
2.7      225.     -2.1
7800.    5300.    .9
7.0      90.      1.5
7.0      90.      1.5
7.0      90.      1.5
7.0      90.      1.5
7.0      90.      1.5
7.0      90.      1.5
7.0      90.      1.5
7.0      90.      1.5
7.0      90.      1.5
7.0      90.      1.5
5760.    1120.    .5
2.5      270.     8.3
2.5      270.     8.3
2.5      270.     8.3
2.5      270.     8.3
2.5      270.     8.3
2.5      270.     8.3
2.5      270.     8.3
2.5      270.     8.3
2.5      270.     8.3
2.5      270.     8.3
3360.    6240.    .9
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1.0      345.     -1.6
1.0      345.     -1.6
1.0      345.     -1.6
1.0      345.     -1.6
1.0      345.     -1.6
1.0      345.     -1.6
1.0      345.     -1.6
1.0      345.     -1.6
1.0      345.     -1.6
1760.    5120.    .9
2.2      140.     -2.1
2.7      114.     -2.1
5.6      114.     -2.1
4.9      115.     -2.1
4.3      115.     -2.1
```

4.0	110.	-2.1
4.0	125.	-2.1
3.6	136.	-2.1
3.1	140.	-2.1
2.7	147.	-2.1
4640.	2720.	0.9
4.3	225.	-2.1
4.0	225.	-2.1
4.0	225.	-2.1
3.6	225.	-2.1
3.1	225.	-2.1
2.7	225.	-2.1
2.7	225.	-2.1
2.7	225.	-2.1
2.7	225.	-2.1
2.7	225.	-2.1
7800.	5300.	.9
7.0	70.	1.5
7.0	70.	1.5
7.0	70.	1.5
7.0	70.	1.5
7.0	70.	1.5
7.0	70.	1.5
7.0	70.	1.5
7.0	70.	1.5
7.0	70.	1.5
7.0	70.	1.5
5760.	1120.	.5
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2.5	210.	8.3
2.5	210.	8.3
2.5	210.	8.3
2.5	210.	8.3
2.5	210.	8.3
2.5	210.	8.3
2.5	210.	8.3
2.5	210.	8.3
3360.	6240.	.9
1.0	345.	-1.6
1.0	345.	-1.6
1.0	345.	-1.6
1.0	345.	-1.6
1.0	345.	-1.6
1.0	345.	-1.6
1.0	345.	-1.6
1.0	345.	-1.6
1.0	345.	-1.6
1.0	345.	-1.6
1760.	5120.	.9
2.2	140.	-2.1
2.7	114.	-2.1
5.6	114.	-2.1
4.9	115.	-2.1
4.3	115.	-2.1
4.0	110.	-2.1
4.0	125.	-2.1
3.6	136.	-2.1
3.1	140.	-2.1
2.7	147.	-2.1

4640.	2720.	0.9
6.0	225.	-2.1
5.6	225.	-2.1
4.9	225.	-2.1
4.3	225.	-2.1
3.6	225.	-2.1
2.2	225.	-2.1
2.2	225.	-2.1
2.2	225.	-2.1
2.2	225.	-2.1
2.2	225.	-2.1
7800.	5300.	.9
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7.0	90.	1.5
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7.0	90.	1.5
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2.5	120.	8.3
3360.	6240.	.9
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1.0	270.	-1.6
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1.0	270.	-1.6
1.0	270.	-1.6
1.0	270.	-1.6
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2.2	114.	-2.1
3.4	119.	-2.1
4.5	114.	-2.1
6.0	132.	-2.1
5.6	125.	-2.1
4.9	114.	-2.1
4.3	114.	-2.1
3.6	114.	-2.1
2.2	160.	-2.1
4640.	2720.	0.9
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5.6	225.	-2.1
4.9	225.	-2.1
4.3	225.	-2.1

3.6	225.	-2.1
2.2	225.	-2.1
2.2	225.	-2.1
2.2	225.	-2.1
2.2	225.	-2.1
2.2	225.	-2.1
7800.	5300.	.9
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7.0	100.	1.5
7.0	100.	1.5
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7.0	100.	1.5
7.0	100.	1.5
7.0	100.	1.5
7.0	100.	1.5
5760.	1120.	.5
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2.5	110.	8.3
2.5	110.	8.3
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2.5	110.	8.3
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3360.	6240.	.9
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1760.	5120.	.9
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3.4	119.	-2.1
4.5	114.	-2.1
6.0	132.	-2.1
5.6	125.	-2.1
4.9	114.	-2.1
4.3	114.	-2.1
3.6	114.	-2.1
2.2	160.	-2.1
4040.	2720.	0.9
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6

6.7	235.	-2.6
7800.	5300.	.9
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
5760.	1120.	.5
2.0	250.	7.2
2.0	250.	7.2
2.0	250.	7.2
2.0	250.	7.2
2.0	250.	7.2
2.0	250.	7.2
2.0	250.	7.2
2.0	250.	7.2
2.0	250.	7.2
2.0	250.	7.2
3360.	6240.	.9
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1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1760.	5120.	.9
3.1	150.	-2.6
3.8	126.	-2.6
4.5	130.	-2.6
5.4	135.	-2.6
5.4	118.	-2.6
4.9	118.	-2.6
3.8	119.	-2.6
3.4	141.	-2.6
2.2	139.	-2.6
2.2	140.	-2.6
4640.	2720.	0.9
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
6.7	235.	-2.6
7800.	5300.	.9
7.0	90.	3.1
7.0	90.	3.1
7.0	90.	3.1

7.0	90.	3.1
7.0	90.	3.1
7.0	90.	3.1
7.0	90.	3.1
7.0	90.	3.1
7.0	90.	3.1
7.0	90.	3.1
5760.	1120.	.5
2.0	320.	7.2
2.0	320.	7.2
2.0	320.	7.2
2.0	320.	7.2
2.0	320.	7.2
2.0	320.	7.2
2.0	320.	7.2
2.0	320.	7.2
2.0	320.	7.2
2.0	320.	7.2
3360.	6240.	.9
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
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1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1760.	5120.	.9
2.9	114.	-2.6
4.5	126.	-2.6
7.6	135.	-2.6
7.4	121.	-2.6
5.8	113.	-2.6
7.8	114.	-2.6
5.8	114.	-2.6
6.5	114.	-2.6
4.3	140.	-2.6
2.2	160.	-2.6
4640.	2720.	0.9
4.5	170.	-2.6
4.5	170.	-2.6
4.5	170.	-2.6
4.5	170.	-2.6
4.5	170.	-2.6
4.5	170.	-2.6
4.5	170.	-2.6
4.5	170.	-2.6
4.5	170.	-2.6
4.5	170.	-2.6
7800.	5300.	.9
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1
7.0	110.	3.1

7.0	110.	3.1
7.0	110.	3.1
5760.	1120.	.5
2.0	210.	7.2
2.0	210.	7.2
2.0	210.	7.2
2.0	210.	7.2
2.0	210.	7.2
2.0	210.	7.2
2.0	210.	7.2
2.0	210.	7.2
2.0	210.	7.2
2.0	210.	7.2
3360.	6240.	.9
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1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1.0	360.	-2.2
1760.	5120.	.9
2.9	114.	-2.6
4.5	126.	-2.6
7.6	135.	-2.6
7.4	121.	-2.6
5.8	113.	-2.6
7.8	114.	-2.6
5.8	114.	-2.6
6.5	114.	-2.6
4.3	140.	-2.6
2.2	160.	-2.6
4640.	2720.	0.9
5.0	105.	-2.6
5.0	105.	-2.6
5.0	105.	-2.6
5.0	105.	-2.6
5.0	105.	-2.6
5.0	105.	-2.6
5.0	105.	-2.6
5.0	105.	-2.6
5.0	105.	-2.6
5.0	105.	-2.6
7800.	5300.	.9
7.0	120.	3.1
7.0	120.	3.1
7.0	120.	3.1
7.0	120.	3.1
7.0	120.	3.1
7.0	120.	3.1
7.0	120.	3.1
7.0	120.	3.1
7.0	120.	3.1
7.0	120.	3.1
5760.	1120.	.5
2.0	160.	7.2
2.0	160.	7.2

2.0	160.	7.2
2.0	160.	7.2
2.0	160.	7.2
2.0	160.	7.2
2.0	160.	7.2
2.0	160.	7.2
2.0	160.	7.2
2.0	160.	7.2
3360.	6240.	.9
1.0	210.	-2.2
1.0	210.	-2.2
1.0	210.	-2.2
1.0	210.	-2.2
1.0	210.	-2.2
1.0	210.	-2.2
1.0	210.	-2.2
1.0	210.	-2.2
1.0	210.	-2.2
1.0	210.	-2.2
1760.	5120.	.9
2.9	114.	-2.6
4.5	126.	-2.6
7.6	135.	-2.6
7.4	121.	-2.6
5.8	113.	-2.6
7.8	114.	-2.6
5.8	114.	-2.6
6.5	114.	-2.6
4.3	140.	-2.6
2.2	160.	-2.6
4640.	2720.	0.9
4.5	100.	-1.7
4.5	100.	-1.7
4.5	100.	-1.7
4.5	100.	-1.7
4.5	100.	-1.7
4.5	100.	-1.7
4.5	100.	-1.7
4.5	100.	-1.7
4.5	100.	-1.7
4.5	100.	-1.7
7800.	5300.	.9
6.8	110.	8.4
6.8	110.	8.4
6.8	110.	8.4
6.8	110.	8.4
6.8	110.	8.4
6.8	110.	8.4
6.8	110.	8.4
6.8	110.	8.4
6.8	110.	8.4
6.8	110.	8.4
5760.	1120.	.5
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2.0	60.	7.2
2.0	60.	7.2
2.0	60.	7.2
2.0	60.	7.2
2.0	60.	7.2
2.0	60.	7.2

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2.0	60.	7.2
2.0	60.	7.2
3360.	6240.	.9
1.0	285.	-.4
1.0	285.	-.4
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1.0	285.	-.4
1.0	285.	-.4
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1.0	285.	-.4
1.0	285.	-.4
1.0	285.	-.4
1760.	5120.	.9
2.2	125.	-1.7
4.9	90.	-1.7
6.7	105.	-1.7
6.7	116.	-1.7
6.5	117.	-1.7
5.6	190.	-1.7
4.3	150.	-1.7
4.6	130.	-1.7
2.7	125.	-1.7
3.8	120.	-1.7
4640.	2720.	0.9
4.5	240.	-1.7
4.5	240.	-1.7
4.5	240.	-1.7
4.5	240.	-1.7
4.5	240.	-1.7
4.5	240.	-1.7
4.5	240.	-1.7
4.5	240.	-1.7
4.5	240.	-1.7
4.5	240.	-1.7
7800.	5300.	.9
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
5760.	1120.	.5
2.0	330.	7.2
2.0	330.	7.2
2.0	330.	7.2
2.0	330.	7.2
2.0	330.	7.2
2.0	330.	7.2
2.0	330.	7.2
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2.0	330.	7.2
2.0	330.	7.2
3360.	6240.	.9
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1.0	300.	-.4
1.0	300.	-.4
1.0	300.	-.4
1.0	300.	-.4
1.0	300.	-.4
1.0	300.	-.4
1.0	300.	-.4
1760.	5120.	.9
2.2	95.	-1.7
2.7	140.	-1.7
5.1	150.	-1.7
6.9	123.	-1.7
6.5	124.	-1.7
5.6	111.	-1.7
7.2	112.	-1.7
6.3	130.	-1.7
4.5	143.	-1.7
2.2	133.	-1.7
4040.	2720.	0.9
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
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6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
7800.	5300.	.9
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
5760.	1120.	.5
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
3360.	6240.	.9
1.0	0.	-.4
1.0	0.	-.4
1.0	0.	-.4
1.0	0.	-.4
1.0	0.	-.4
1.0	0.	-.4

1.0	0.	-.4
1.0	0.	-.4
1.0	0.	-.4
1.0	0.	-.4
1760.	5120.	.9
2.2	95.	-1.7
2.7	140.	-1.7
5.1	150.	-1.7
6.9	123.	-1.7
6.5	124.	-1.7
5.6	111.	-1.7
7.2	112.	-1.7
6.3	130.	-1.7
4.5	143.	-1.7
2.2	133.	-1.7
4640.	2720.	0.9
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
6.7	235.	-1.7
7800.	5300.	.9
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
7.0	110.	8.4
5760.	1120.	.5
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
2.0	235.	7.2
3360.	6240.	.9
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1.0	45.	-.4
1.0	45.	-.4
1.0	45.	-.4
1.0	45.	-.4
1.0	45.	-.4
1.0	45.	-.4
1.0	45.	-.4
1760.	5120.	.9
2.2	95.	-1.7

2.7	140.	-1.7
5.1	150.	-1.7
6.9	123.	-1.7
6.5	124.	-1.7
5.6	111.	-1.7
7.2	112.	-1.7
6.3	130.	-1.7
4.5	143.	-1.7
2.2	133.	-1.7
4040.	2720.	0.9
4.5	213.	3.1
4.5	213.	3.1
4.5	213.	3.1
4.5	213.	3.1
4.5	213.	3.1
4.5	213.	3.1
4.5	213.	3.1
4.5	213.	3.1
4.5	213.	3.1
4.5	213.	3.1
7800.	5300.	.9
7.0	120.	13.6
7.0	120.	13.6
7.0	120.	13.6
7.0	120.	13.6
7.0	120.	13.6
7.0	120.	13.6
7.0	120.	13.6
7.0	120.	13.6
7.0	120.	13.6
7.0	120.	13.6
5760.	1120.	.5
1.5	45.	7.8
1.5	45.	7.8
1.5	45.	7.8
1.5	45.	7.8
1.5	45.	7.8
1.5	45.	7.8
1.5	45.	7.8
1.5	45.	7.8
1.5	45.	7.8
1.5	45.	7.8
3360.	6240.	.9
1.0	135.	4.6
1.0	135.	4.6
1.0	135.	4.6
1.0	135.	4.6
1.0	135.	4.6
1.0	135.	4.6
1.0	135.	4.6
1.0	135.	4.6
1.0	135.	4.6
1.0	135.	4.6
1760.	5120.	.8
2.2	358.	3.1
2.2	71.	3.1
2.2	134.	3.1
3.6	140.	3.1
4.0	125.	3.1
4.9	121.	3.1

2.7	128.	3.1
3.8	135.	3.1
4.0	135.	3.1
5.6	125.	3.1
4640.	2720.	0.9
9.0	100.	3.1
9.0	100.	3.1
9.0	100.	3.1
9.0	100.	3.1
9.0	100.	3.1
9.0	100.	3.1
9.0	100.	3.1
9.0	100.	3.1
9.0	100.	3.1
9.0	100.	3.1
7800.	5300.	.9
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
5760.	1120.	.5
1.5	40.	7.8
1.5	40.	7.8
1.5	40.	7.8
1.5	40.	7.8
1.5	40.	7.8
1.5	40.	7.8
1.5	40.	7.8
1.5	40.	7.8
1.5	40.	7.8
1.5	40.	7.8
3360.	6240.	.9
1.0	165.	4.6
1.0	165.	4.6
1.0	165.	4.6
1.0	165.	4.6
1.0	165.	4.6
1.0	165.	4.6
1.0	165.	4.6
1.0	165.	4.6
1.0	165.	4.6
1.0	165.	4.6
1760.	5120.	.9
2.2	358.	3.1
2.2	71.	3.1
2.2	134.	3.1
3.6	140.	3.1
4.0	125.	3.1
4.9	121.	3.1
2.7	128.	3.1
3.8	135.	3.1
4.0	135.	3.1
5.6	125.	3.1
4640.	2720.	0.9

4.5	100.	3.1
4.5	100.	3.1
4.5	100.	3.1
4.5	100.	3.1
4.5	100.	3.1
4.5	100.	3.1
4.5	100.	3.1
4.5	100.	3.1
4.5	100.	3.1
4.5	100.	3.1
7800.	5300.	.9
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
7.0	100.	13.6
5760.	1120.	.5
1.5	35.	7.8
1.5	35.	7.8
1.5	35.	7.8
1.5	35.	7.8
1.5	35.	7.8
1.5	35.	7.8
1.5	35.	7.8
1.5	35.	7.8
1.5	35.	7.8
1.5	35.	7.8
3360.	6240.	.9
1.0	105.	4.6
1.0	105.	4.6
1.0	105.	4.6
1.0	105.	4.6
1.0	105.	4.6
1.0	105.	4.6
1.0	105.	4.6
1.0	105.	4.6
1.0	105.	4.6
1.0	105.	4.6
1760.	5120.	.9
2.2	140.	5.1
2.2	56.	5.1
2.2	110.	5.1
4.0	125.	5.1
4.5	116.	5.1
5.1	101.	5.1
4.5	103.	5.1
4.9	115.	5.1
5.1	120.	5.1
5.6	121.	5.1
4640.	2720.	0.9
4.5	100.	5.1
4.5	100.	5.1
4.5	100.	5.1
4.5	100.	5.1
4.5	100.	5.1

4.5	100.	5.1
4.5	100.	5.1
4.5	100.	5.1
4.5	100.	5.1
4.5	100.	5.1
7800.	5300.	.9
7.0	110.	13.6
7.0	110.	13.6
7.0	110.	13.6
7.0	110.	13.6
7.0	110.	13.6
7.0	110.	13.6
7.0	110.	13.6
7.0	110.	13.6
7.0	110.	13.6
7.0	110.	13.6
5760.	1120.	.5
1.5	20.	7.8
1.5	20.	7.8
1.5	20.	7.8
1.5	20.	7.8
1.5	20.	7.8
1.5	20.	7.8
1.5	20.	7.8
1.5	20.	7.8
1.5	20.	7.8
1.5	20.	7.8
3360.	6240.	.9
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1.0	120.	4.6
1.0	120.	4.6
1.0	120.	4.6
1.0	120.	4.6
1.0	120.	4.6
1.0	120.	4.6
1.0	120.	4.6
1.0	120.	4.6
1.0	120.	4.6
1760.	5120.	.9
2.2	140.	5.1
2.2	56.	5.1
2.2	110.	5.1
4.0	125.	5.1
4.5	116.	5.1
5.1	101.	5.1
4.5	103.	5.1
4.9	115.	5.1
5.1	120.	5.1
5.6	121.	5.1
4040.	2720.	0.9
4.5	95.	5.
4.5	95.	5.
4.5	95.	5.
4.5	95.	5.
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4.5	95.	5.

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7.0	110.	16.3
7.0	110.	16.3
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7.0	110.	16.3
5760.	1120.	.5
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3360.	6240.	.9
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1.0	180.	10.1
1.0	180.	10.1
1.0	180.	10.1
1760.	5120.	.9
2.2	271.	5.9
2.2	23.	5.9
2.2	110.	5.9
2.2	142.	5.9
2.2	128.	5.9
2.9	109.	5.9
4.3	97.	5.9
4.9	100.	5.9
5.1	94.	5.9
4.3	95.	5.9
4040.	2720.	0.9
2.2	70.	5.9
2.2	70.	5.9
2.2	70.	5.9
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7.0	105.	16.3
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2.0	310.	9.4
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2.0	310.	9.4
3360.	6240.	.9
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2.5	165.	10.1
2.5	165.	10.1
1760.	5120.	.9
2.2	271.	5.9
2.2	23.	5.9
2.2	110.	5.9
2.2	142.	5.9
2.2	128.	5.9
2.9	109.	5.9
4.3	97.	5.9
4.9	100.	5.9
5.1	94.	5.9
4.3	95.	5.9
4640.	2720.	0.9
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4.5	360.	10.5
4.5	360.	10.5
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4.5	360.	10.5
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7.0	100.	16.3
7.0	100.	16.3
7.0	100.	16.3
7.0	100.	16.3
7.0	100.	16.3
7.0	100.	16.3
7.0	100.	16.3

7.0	100.	16.3
5760.	1120.	.5
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2.5	150.	10.1
2.5	150.	10.1
1760.	5120.	.9
7.4	330.	10.5
4.5	304.	10.5
4.7	305.	10.5
4.0	300.	10.5
2.5	240.	10.5
2.2	155.	10.5
2.2	116.	10.5
3.6	130.	10.5
6.7	116.	10.5
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4.5	333.	10.5
4.5	333.	10.5
4.5	333.	10.5
4.5	333.	10.5
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7800.	5300.	.9
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7.0	85.	16.3
5760.	1120.	.5
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2.0	350.	9.4

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2.0	350.	9.4
2.0	350.	9.4
2.0	350.	9.4
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2.5	150.	10.1
2.5	150.	10.1
2.5	150.	10.1
2.5	150.	10.1
1760.	5120.	.9
7.4	330.	10.5
4.5	304.	10.5
4.7	305.	10.5
4.0	300.	10.5
2.5	240.	10.5
2.2	155.	10.5
2.2	116.	10.5
3.6	130.	10.5
6.7	116.	18.5
8.3	114.	10.5
4640.	2720.	0.9
4.5	360.	14.7
4.5	360.	14.7
4.5	360.	14.7
4.5	360.	14.7
4.5	360.	14.7
4.5	360.	14.7
4.5	360.	14.7
4.5	360.	14.7
4.5	360.	14.7
4.5	360.	14.7
7800.	5300.	.9
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4.5	360.	12.2
4.5	360.	12.2
4.5	360.	12.2
4.5	360.	12.2
4.5	360.	12.2
4.5	360.	12.2
4.5	360.	12.2

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4.5	360.	12.2
3360.	6240.	.9
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5.0	165.	13.9
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5.0	165.	13.9
5.0	165.	13.9
5.0	165.	13.9
5.0	165.	13.9
5.0	165.	13.9
5.0	165.	13.9
1760.	5120.	.8
3.1	314.	14.7
6.0	306.	14.7
4.9	322.	14.7
3.1	305.	14.7
2.7	300.	14.7
3.4	266.	14.7
2.2	240.	14.7
2.2	106.	14.7
4.3	110.	14.7
4.7	125.	14.7
4640.	2720.	0.9
4.5	340.	14.7
4.5	340.	14.7
4.5	340.	14.7
4.5	340.	14.7
4.5	340.	14.7
4.5	340.	14.7
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4.5	340.	14.7
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7800.	5300.	.9
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7.0	270.	19.2
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5760.	1120.	.5
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4.5	40.	12.2
4.5	40.	12.2
4.5	40.	12.2
4.5	40.	12.2
3360.	6240.	.9
5.0	150.	13.9
5.0	150.	13.9

5.0	150.	13.9
5.0	150.	13.9
5.0	150.	13.9
5.0	150.	13.9
5.0	150.	13.9
5.0	150.	13.9
5.0	150.	13.9
5.0	150.	13.9
1760.	5120.	.9
3.1	314.	14.7
6.0	306.	14.7
4.9	322.	14.7
3.1	305.	14.7
2.7	300.	14.7
3.4	266.	14.7
2.2	240.	14.7
2.2	106.	14.7
4.3	110.	14.7
4.7	125.	14.7
4640.	2720.	0.9
4.5	340.	14.7
4.5	340.	14.7
4.5	340.	14.7
4.5	340.	14.7
4.5	340.	14.7
4.5	340.	14.7
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4.5	340.	14.7
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7.0	280.	19.2
7.0	280.	19.2
7.0	280.	19.2
5760.	1120.	.5
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4.5	360.	12.2
4.5	360.	12.2
4.5	360.	12.2
3360.	6240.	.9
5.0	195.	13.9
5.0	195.	13.9
5.0	195.	13.9
5.0	195.	13.9
5.0	195.	13.9
5.0	195.	13.9
5.0	195.	13.9

5.0	195.	13.9
5.0	195.	13.9
5.0	195.	13.9
1760.	5120.	.9
3.1	314.	14.7
6.0	306.	14.7
4.9	322.	14.7
3.1	305.	14.7
2.7	300.	14.7
3.4	266.	14.7
2.2	240.	14.7
2.2	106.	14.7
4.3	110.	14.7
4.7	125.	14.7
4640.	2720.	0.9
2.2	260.	14.7
2.2	260.	14.7
2.2	260.	14.7
2.2	260.	14.7
2.2	260.	14.7
2.2	260.	14.7
2.2	260.	14.7
2.2	260.	14.7
2.2	260.	14.7
2.2	260.	14.7
7800.	5300.	.9
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7.0	280.	19.2
7.0	280.	19.2
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7.0	280.	19.2
5760.	1120.	.5
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4.5	210.	12.2
4.5	210.	12.2
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4.5	210.	12.2
4.5	210.	12.2
3360.	6240.	.9
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4.5	210.	13.9
4.5	210.	13.9
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4.5	210.	13.9
4.5	210.	13.9
4.5	210.	13.9
1760.	5120.	.9
3.1	314.	14.7

6.0	306.	14.7			
4.9	322.	14.7			
3.1	305.	14.7			
2.7	300.	14.7			
3.4	266.	14.7			
2.2	240.	14.7			
2.2	106.	14.7			
4.3	110.	14.7			
4.7	125.	14.7			
1760.	5120.	6666666666			
5760.	1120.	66666			
1760.	5120.	6666666666			
5760.	1120.	66666			
1760.	5120.	6666666666			
5760.	1120.	66666			
1760.	5120.	6666666666			
5760.	1120.	66666			
1760.	5120.	6666666666			
5760.	1120.	66666			
1760.	5120.	6666666666			
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1760.	5120.	4446666555			
5760.	1120.	44665			
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1760.	5120.	4455555566			
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1760.	5120.	4455555566			
5760.	1120.	44566			
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5760.	1120.	44566			
1760.	5120.	4455555544			
5760.	1120.	44566			
4640.	2720.	3.15	100.	0.	273.
5760.	3840.				
4900.	2080.				

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3360.     2560.
4320.     3520.
7040.     2560.
160.      4960.
640.      5440.
2560.     3840.
1760.     4960.
1440.     5440.
3680.     4960.
3680.     5440.
3520.     6560.
4960.     4640.
4480.     5440.
5440.     5440.
5440.     7360.
7840.     5760.
5760.     1120.
Q FIN Q FIN Q FIN Q FIN Q FIN Q FIN Q FIN Q FIN Q FIN Q FIN Q FIN Q FIN Q FIN Q FIN
```

Listings of Inputs for Day 2

15 September 1978

9.9	122.	9.0
10.3	127.	8.5
8.5	126.	8.7
12.0	135.	11.8
11.2	156.	12.0
4640.	2720.	0.9
9.0	135.	8.5
9.0	135.	9.0
9.0	135.	10.0
9.0	135.	11.0
9.0	135.	12.0
9.0	135.	12.0
9.0	135.	12.0
9.0	135.	12.0
9.0	135.	12.0
9.0	135.	12.0
7800.	5300.	.9
5.0	75.	4.1
5.0	75.	4.1
5.0	75.	4.1
5.0	75.	4.1
5.0	75.	4.1
5.0	75.	4.1
5.0	75.	4.1
5.0	75.	4.1
5.0	75.	4.1
5.0	75.	4.1
5760.	1120.	.5
4.0	90.	9.4
4.0	90.	9.4
4.0	90.	9.4
4.0	90.	9.4
4.0	90.	9.4
4.0	90.	9.4
4.0	90.	9.4
4.0	90.	9.4
4.0	90.	9.4
4.0	90.	9.4
3360.	6240.	.9
1.3	360.	4.5
1.3	360.	4.5
1.3	360.	4.5
1.3	360.	4.5
1.3	360.	4.5
1.3	360.	4.5
1.3	360.	4.5
1.3	360.	4.5
1.3	360.	4.5
1.3	360.	4.5
1760.	5120.	.9
2.5	110.	7.0
4.5	120.	7.3
8.0	115.	7.5
10.0	115.	7.8
10.0	115.	8.0
9.0	120.	8.5
9.0	125.	9.0
9.0	130.	10.0
9.0	140.	11.0
9.0	150.	12.0

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NHRS=24,NS=1,NR=19,IWND=1,DEG=23. $END
450.      0.0       0.0       1900.     0.0       1.0                 1    1
   5    4    3    3    2    1    0    1    3    4    5    4    3    2    2    1
   0    2    4    6    5    4    2    2    1    0    0    2    3    6    3    2
   2    3    3    2    0    4    5    7    5    4    3    4    3    2    0    3
   4    5    6    5    4    4    3    2    1    4    6    8    6    5    5    4
   3    1    1    3    4    5    6    5    5    5    4    3    1    3    5    6
   7    6    6    5    4    3    2    4    6    7    7    6    5    4    3    3
   2    4    6    8
4640.     2720.     0.9
9.0       112.      9.0
10.3      112.      8.5
8.5       112.      8.7
12.0      112.      11.8
11.2      112.      12.0
11.2      112.      12.0
11.2      112.      12.0
11.2      112.      12.0
11.2      112.      12.0
11.2      112.      12.0
7800.     5300.     .9
5.0       60.       4.1
5.0       60.       4.1
5.0       60.       4.1
5.0       60.       4.1
5.0       60.       4.1
5.0       60.       4.1
5.0       60.       4.1
5.0       60.       4.1
5.0       60.       4.1
5.0       60.       4.1
5760.     1120.     .5
4.0       120.      9.4
4.0       120.      9.4
4.0       120.      9.4
4.0       120.      9.4
4.0       120.      9.4
4.0       120.      9.4
4.0       120.      9.4
4.0       120.      9.4
4.0       120.      9.4
4.0       120.      9.4
3360.     6240.     .9
1.3       285.      4.5
1.3       285.      4.5
1.3       285.      4.5
1.3       285.      4.5
1.3       285.      4.5
1.3       285.      4.5
1.3       285.      4.5
1.3       285.      4.5
1.3       285.      4.5
1.3       285.      4.5
1760.     5120.     .9
2.7       100.      7.0
4.7       120.      7.7
8.0       115.      7.8
10.1      118.0     7.8
11.2      117.      8.0
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4640.	2720.	0.9
9.0	135.	8.5
9.0	135.	9.0
9.0	135.	10.0
9.0	135.	11.0
9.0	135.	12.0
9.0	135.	12.0
9.0	135.	12.0
9.0	135.	12.0
9.0	135.	12.0
9.0	135.	12.0
7800.	5300.	.9
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5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5760.	1120.	.5
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4.0	60.	9.4
4.0	60.	9.4
4.0	60.	9.4
4.0	60.	9.4
4.0	60.	9.4
4.0	60.	9.4
4.0	60.	9.4
4.0	60.	9.4
4.0	60.	9.4
3360.	6240.	.9
1.3	225.	4.5
1.3	225.	4.5
1.3	225.	4.5
1.3	225.	4.5
1.3	225.	4.5
1.3	225.	4.5
1.3	225.	4.5
1.3	225.	4.5
1.3	225.	4.5
1.3	225.	4.5
1760.	5120.	.9
2.5	110.	7.0
4.5	120.	7.3
8.0	115.	7.5
10.0	115.	7.8
10.0	115.	8.0
9.0	120.	8.5
9.0	125.	9.0
9.0	130.	10.0
9.0	140.	11.0
9.0	150.	12.0
4640.	2720.	0.9
7.8	112.	8.9
6.7	112.	9.3
8.3	112.	10.5
8.3	112.	12.0

7.8	112.	12.5
7.8	112.	12.5
7.8	112.	12.5
7.8	112.	12.5
7.8	112.	12.5
7.8	112.	12.5
7800.	5300.	.9
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5.0	90.	4.1
5760.	1120.	.5
4.0	150.	9.4
4.0	150.	9.4
4.0	150.	9.4
4.0	150.	9.4
4.0	150.	9.4
4.0	150.	9.4
4.0	150.	9.4
4.0	150.	9.4
4.0	150.	9.4
4.0	150.	9.4
3360.	6240.	.9
1.3	345.	4.5
1.3	345.	4.5
1.3	345.	4.5
1.3	345.	4.5
1.3	345.	4.5
1.3	345.	4.5
1.3	345.	4.5
1.3	345.	4.5
1.3	345.	4.5
1.3	345.	4.5
1760.	5120.	.9
2.2	110.	6.8
4.5	120.	7.2
7.8	114.	8.0
8.9	110.	8.1
8.9	115.	8.4
7.6	120.	8.9
6.7	130.	9.3
8.3	120.	10.5
8.3	140.	12.0
7.8	145.	12.5
4640.	2720.	0.9
9.0	90.	9.0
9.0	90.	9.5
9.0	90.	11.0
8.5	90.	12.0
8.0	90.	12.5
8.0	90.	12.5
8.0	90.	12.5
8.0	90.	12.5
8.0	90.	12.5

8.0	90.	12.5
7800.	5300.	.9
6.0	105.	4.0
6.0	105.	4.0
6.0	105.	4.0
6.0	105.	4.0
6.0	105.	4.0
6.0	105.	4.0
6.0	105.	4.0
6.0	105.	4.0
6.0	105.	4.0
6.0	105.	4.0
5760.	1120.	.5
3.5	180.	10.0
3.5	180.	10.0
3.5	180.	10.0
3.5	180.	10.0
3.5	180.	10.0
3.5	180.	10.0
3.5	180.	10.0
3.5	180.	10.0
3.5	180.	10.0
3.5	180.	10.0
3360.	6240.	.9
1.3	270.	3.9
1.3	270.	3.9
1.3	270.	3.9
1.3	270.	3.9
1.3	270.	3.9
1.3	270.	3.9
1.3	270.	3.9
1.3	270.	3.9
1.3	270.	3.9
1.3	270.	3.9
1760.	5120.	.9
2.2	110.	6.0
6.0	120.	7.2
8.0	115.	8.0
9.0	115.	8.2
9.5	115.	8.5
9.0	120.	9.0
9.0	120.	9.5
9.0	120.	11.0
8.5	135.	12.0
8.0	145.	12.5
4640.	2720.	0.9
10.1	115.	8.6
10.3	115.	8.6
11.2	115.	8.6
11.8	115.	8.6
8.9	115.	8.6
8.7	115.	8.6
8.7	115.	8.6
8.7	115.	8.6
8.7	115.	8.6
8.7	115.	8.6
7800.	5300.	.9
5.5	105.	4.0
5.5	105.	4.0
5.5	105.	4.0

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5.5	105.	4.0
5.5	105.	4.0
5.5	105.	4.0
5.5	105.	4.0
5.5	105.	4.0
5.5	105.	4.0
5760.	1120.	.5
3.5	170.	10.0
3.5	170.	10.0
3.5	170.	10.0
3.5	170.	10.0
3.5	170.	10.0
3.5	170.	10.0
3.5	170.	10.0
3.5	170.	10.0
3.5	170.	10.0
3.5	170.	10.0
3360.	6240.	.9
1.3	285.	3.9
1.3	285.	3.9
1.3	285.	3.9
1.3	285.	3.9
1.3	285.	3.9
1.3	285.	3.9
1.3	285.	3.9
1.3	285.	3.9
1.3	285.	3.9
1.3	285.	3.9
1760.	5120.	.9
2.2	100.	5.5
7.8	120.	7.2
8.9	120.	7.7
8.9	115.	8.2
10.1	115.	8.6
10.3	118.	9.4
11.2	116.	10.0
11.8	115.	12.0
8.9	135.	12.4
8.7	150.	12.5
4640.	2720.	0.9
9.0	90.	8.5
9.5	90.	8.5
10.	90.	8.5
10.	90.	8.5
7.0	90.	8.5
6.5	90.	8.5
6.5	90.	8.5
6.5	90.	8.5
6.5	90.	8.5
6.5	90.	8.5
7800.	5300.	.9
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0

10.0	105.	4.0
10.0	105.	4.0
5760.	1120.	.5
3.5	60.	10.0
3.5	60.	10.0
3.5	60.	10.0
3.5	60.	10.0
3.5	60.	10.0
3.5	60.	10.0
3.5	60.	10.0
3.5	60.	10.0
3.5	60.	10.0
3.5	60.	10.0
3360.	6240.	.9
1.0	315.	3.9
1.0	315.	3.9
1.0	315.	3.9
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1.0	315.	3.9
1.0	315.	3.9
1.0	315.	3.9
1.0	315.	3.9
1.0	315.	3.9
1760.	5120.	.9
2.2	100.	5.5
6.0	125.	6.5
7.0	130.	7.5
8.5	125.	8.0
9.0	115.	8.5
9.5	117.	10.0
10.0	117.	10.5
10.0	117.	11.5
7.0	130.	12.0
6.5	150.	12.5
4640.	2720.	0.9
7.8	90.	7.5
9.3	90.	7.5
8.9	90.	7.5
6.9	90.	7.5
4.9	90.	7.5
4.9	90.	7.5
4.9	90.	7.5
4.9	90.	7.5
4.9	90.	7.5
4.9	90.	7.5
7800.	5300.	.9
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
10.0	105.	4.0
5760.	1120.	.5
3.5	150.	10.0
3.5	150.	10.0

3.5	150.	10.0
3.5	150.	10.0
3.5	150.	10.0
3.5	150.	10.0
3.5	150.	10.0
3.5	150.	10.0
3.5	150.	10.0
3.5	150.	10.0
3360.	6240.	.9
1.0	330.	3.9
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1.0	330.	3.9
1.0	330.	3.9
1.0	330.	3.9
1.0	330.	3.9
1.0	330.	3.9
1760.	5120.	.9
2.2	90.	5.4
4.5	126.	6.3
5.6	138.	7.0
6.0	130.	7.1
7.8	115.	7.5
9.3	116.	8.6
8.9	120.	10.5
6.9	123.	11.5
4.9	130.	12.0
4.9	164.	12.4
4640.	2720.	0.9
7.5	95.	8.5
7.5	95.	8.5
7.5	95.	8.5
7.5	95.	8.5
7.5	95.	8.5
7.5	95.	8.5
7.5	95.	8.5
7.5	95.	8.5
7.5	95.	8.5
7.5	95.	8.5
7800.	5300.	.9
10.0	105.	4.1
10.0	105.	4.1
10.0	105.	4.1
10.0	105.	4.1
10.0	105.	4.1
10.0	105.	4.1
10.0	105.	4.1
10.0	105.	4.1
10.0	105.	4.1
10.0	105.	4.1
5760.	1120.	.5
2.0	100.	11.7
2.0	100.	11.7
2.0	100.	11.7
2.0	100.	11.7
2.0	100.	11.7
2.0	100.	11.7
2.0	100.	11.7

2.0	100.	11.7
2.0	100.	11.7
2.0	100.	11.7
3360.	6240.	.9
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1760.	5120.	.9
3.0	90.	6.5
4.5	125.	7.5
6.0	130.	8.0
7.0	125.	8.0
7.5	120.	8.5
8.0	120.	9.5
8.0	125.	11.0
6.0	130.	12.0
5.0	150.	12.5
5.0	165.	12.8
4040.	2720.	0.9
7.4	90.	9.8
7.8	90.	9.8
6.7	90.	9.8
4.7	90.	9.8
5.4	90.	9.8
5.6	90.	9.8
5.6	90.	9.8
5.6	90.	9.8
5.6	90.	9.8
5.6	90.	9.8
7800.	5300.	.9
10.0	120.	4.1
10.0	120.	4.1
10.0	120.	4.1
10.0	120.	4.1
10.0	120.	4.1
10.0	120.	4.1
10.0	120.	4.1
10.0	120.	4.1
10.0	120.	4.1
10.0	120.	4.1
5760.	1120.	.5
2.0	70.	11.7
2.0	70.	11.7
2.0	70.	11.7
2.0	70.	11.7
2.0	70.	11.7
2.0	70.	11.7
2.0	70.	11.7
2.0	70.	11.7
2.0	70.	11.7
2.0	70.	11.7
3360.	6240.	.9
1.0	45.	5.8

1.0	45.	5.8
1.0	45.	5.8
1.0	45.	5.8
1.0	45.	5.8
1.0	45.	5.8
1.0	45.	5.8
1.0	45.	5.8
1.0	45.	5.8
1.0	45.	5.8
1760.	5120.	.9
3.4	90.	7.5
4.5	120.	9.0
6.3	125.	8.5
6.3	120.	9.5
7.4	112.	9.8
7.8	120.	10.6
6.7	130.	12.0
4.7	150.	13.0
5.4	163.	12.8
5.6	164.	13.0
4640.	2720.	0.9
5.0	90.	10.0
5.0	90.	10.0
5.0	90.	10.0
5.0	90.	10.0
5.0	90.	10.0
5.0	90.	10.0
5.0	90.	10.0
5.0	90.	10.0
5.0	90.	10.0
5.0	90.	10.0
7600.	5300.	.9
9.0	120.	4.1
9.0	120.	4.1
9.0	120.	4.1
9.0	120.	4.1
9.0	120.	4.1
9.0	120.	4.1
9.0	120.	4.1
9.0	120.	4.1
9.0	120.	4.1
9.0	120.	4.1
5760.	1120.	.5
2.0	60.	11.7
2.0	60.	11.7
2.0	60.	11.7
2.0	60.	11.7
2.0	60.	11.7
2.0	60.	11.7
2.0	60.	11.7
2.0	60.	11.7
2.0	60.	11.7
2.0	60.	11.7
3360.	6240.	.9
1.0	15.	5.8
1.0	15.	5.8
1.0	15.	5.8
1.0	15.	5.8
1.0	15.	5.8
1.0	15.	5.8

1.0	15.	5.8
1.0	15.	5.8
1.0	15.	5.8
1.0	15.	5.8
1760.	5120.	.9
2.5	110.	8.0
4.0	130.	9.5
4.5	135.	9.5
5.0	135.	9.5
5.0	125.	10.0
5.5	125.	11.0
5.0	130.	12.0
4.0	140.	13.0
3.5	150.	13.0
3.5	160.	13.0
4640.	2720.	0.9
4.5	85.	10.9
4.5	85.	10.9
4.5	85.	10.9
4.5	85.	10.9
4.5	85.	10.9
4.5	85.	10.9
4.5	85.	10.9
4.5	85.	10.9
4.5	85.	10.9
4.5	85.	10.9
7800.	5300.	.9
5.0	105.	4.1
5.0	105.	4.1
5.0	105.	4.1
5.0	105.	4.1
5.0	105.	4.1
5.0	105.	4.1
5.0	105.	4.1
5.0	105.	4.1
5.0	105.	4.1
5.0	105.	4.1
5760.	1120.	.5
2.0	30.	11.7
2.0	30.	11.7
2.0	30.	11.7
2.0	30.	11.7
2.0	30.	11.7
2.0	30.	11.7
2.0	30.	11.7
2.0	30.	11.7
2.0	30.	11.7
2.0	30.	11.7
3360.	6240.	.9
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1.0	30.	5.8
1760.	5120.	.9

2.2	140.	8.5
3.8	133.	9.5
3.8	140.	9.5
4.0	145.	9.3
3.5	130.	10.0
3.6	130.	10.9
2.5	130.	12.0
2.2	135.	13.4
2.5	148.	13.3
2.2	155.	13.2
4640.	2720.	0.9
5.0	90.	11.5
5.0	90.	11.5
5.0	90.	11.5
5.0	90.	11.5
5.0	90.	11.5
5.0	90.	11.5
5.0	90.	11.5
5.0	90.	11.5
5.0	90.	11.5
5.0	90.	11.5
7800.	5300.	.9
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
5760.	1120.	.5
7.5	230.	13.9
7.5	230.	13.9
7.5	230.	13.9
7.5	230.	13.9
7.5	230.	13.9
7.5	230.	13.9
7.5	230.	13.9
7.5	230.	13.9
7.5	230.	13.9
7.5	230.	13.9
3360.	6240.	.9
1.0	45.	10.3
1.0	45.	10.3
1.0	45.	10.3
1.0	45.	10.3
1.0	45.	10.3
1.0	45.	10.3
1.0	45.	10.3
1.0	45.	10.3
1.0	45.	10.3
1.0	45.	10.3
1760.	5120.	.9
3.5	90.	9.5
4.5	110.	10.0
5.0	120.	10.5
5.0	120.	11.0
5.0	115.	11.5

5.0	115.	12.0
5.0	120.	12.5
5.0	125.	13.0
4.5	130.	13.0
4.5	130.	13.5
4640.	2720.	0.9
4.5	80.	13.5
4.5	80.	13.5
4.5	80.	13.5
4.5	80.	13.5
4.5	80.	13.5
4.5	80.	13.5
4.5	80.	13.5
4.5	80.	13.5
4.5	80.	13.5
4.5	80.	13.5
7800.	5300.	.9
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
2.5	45.	3.2
5760.	1120.	.5
7.5	200.	13.9
13.9		
7.5	200.	13.9
7.5	200.	13.9
7.5	200.	13.9
7.5	200.	13.9
7.5	200.	13.9
7.5	200.	13.9
7.5	200.	13.9
7.5	200.	13.9
3360.	6240.	.9
1.0	90.	10.3
1.0	90.	10.3
1.0	90.	10.3
1.0	90.	10.3
1.0	90.	10.3
1.0	90.	10.3
1.0	90.	10.3
1.0	90.	10.3
1.0	90.	10.3
1.0	90.	10.3
1760.	5120.	.9
3.8	90.	11.5
4.7	105.	11.5
3.8	120.	12.0
3.4	120.	12.5
2.7	110.	13.5
3.6	110.	13.4
4.0	110.	13.7
5.1	118.	13.8
3.4	115.	13.8
2.2	125.	13.6

4640.	2720.	0.9
2.5	70.	14.5
2.5	70.	14.5
2.5	70.	14.5
2.5	70.	14.5
2.5	70.	14.5
2.5	70.	14.5
2.5	70.	14.5
2.5	70.	14.5
2.5	70.	14.5
2.5	70.	14.5
7800.	5300.	.9
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5.0	90.	3.2
5.0	90.	3.2
5.0	90.	3.2
5.0	90.	3.2
5.0	90.	3.2
5.0	90.	3.2
5.0	90.	3.2
5.0	90.	3.2
5760.	1120.	.5
7.5	210.	13.9
7.5	210.	13.9
7.5	210.	13.9
7.5	210.	13.9
7.5	210.	13.9
7.5	210.	13.9
7.5	210.	13.9
7.5	210.	13.9
7.5	210.	13.9
7.5	210.	13.9
3360.	6240.	.9
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1.0	120.	10.3
1.0	120.	10.3
1.0	120.	10.3
1.0	120.	10.3
1.0	120.	10.3
1.0	120.	10.3
1.0	120.	10.3
1760.	5120.	.9
3.5	90.	12.5
3.5	110.	12.5
3.5	120.	13.0
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5760.	1120.

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8.0

APPENDIX 8.0

Baseline Monitoring

APPENDIX 8.0

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APPENDIX 8A

C-b Final Environmental Baseline Report, Volume 3

Due to the wide distribution of this document it is not being included in this appendix. If you do not have access to a copy of this document and you have need of it, it can be obtained from the Oil Shale Office.

APPENDIX 8B

C-b Final Environmental Baseline Report, Volume 4

Due to the wide distribution of this document it is not being included in this appendix. If you do not have access to a copy of this document and have need of it, it can be obtained from the Oil Shale Office.

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APPENDIX 8C

QUALITY ASSURANCE PLAN

FOR

AIR RESOURCES MONITORING,

OIL SHALE LEASE TRACT C-b

Prepared for

C-b Oil Shale Venture
2572 G Road
P.O. Box 2687
Grand Junction, Colorado 81501

By

AeroVironment Inc.
145 Vista Avenue
Pasadena, California 91107

June 1978

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1. PROJECT DESCRIPTION

The current air quality and meteorology measurement program on Federal Prototype Oil Shale Lease Tract C-b near Rio Blanco, Colorado, is being performed to comply with the lease agreements between the C-b Shale Oil Venture and the U.S. Department of the Interior, as well as with the additional conditions imposed by the Area Oil Shale Supervisor. The air quality and meteorological monitoring network is being operated to comply with these tract lease terms, and to generate data of adequate quality to meet the regulatory requirements of the U.S. Environmental Protection Agency and the Air Pollution Control Division of the Colorado Department of Health. The air quality parameters being monitored include sulfur dioxide, hydrogen sulfide, carbon monoxide, ozone, oxides of nitrogen, nitric oxide, nitrogen dioxide, and total suspended particulates, while the meteorological parameters include wind speed and direction, temperature, lapse rate, relative humidity, barometric pressure, solar radiation, atmospheric mixing height, turbulence, precipitation and evaporation.

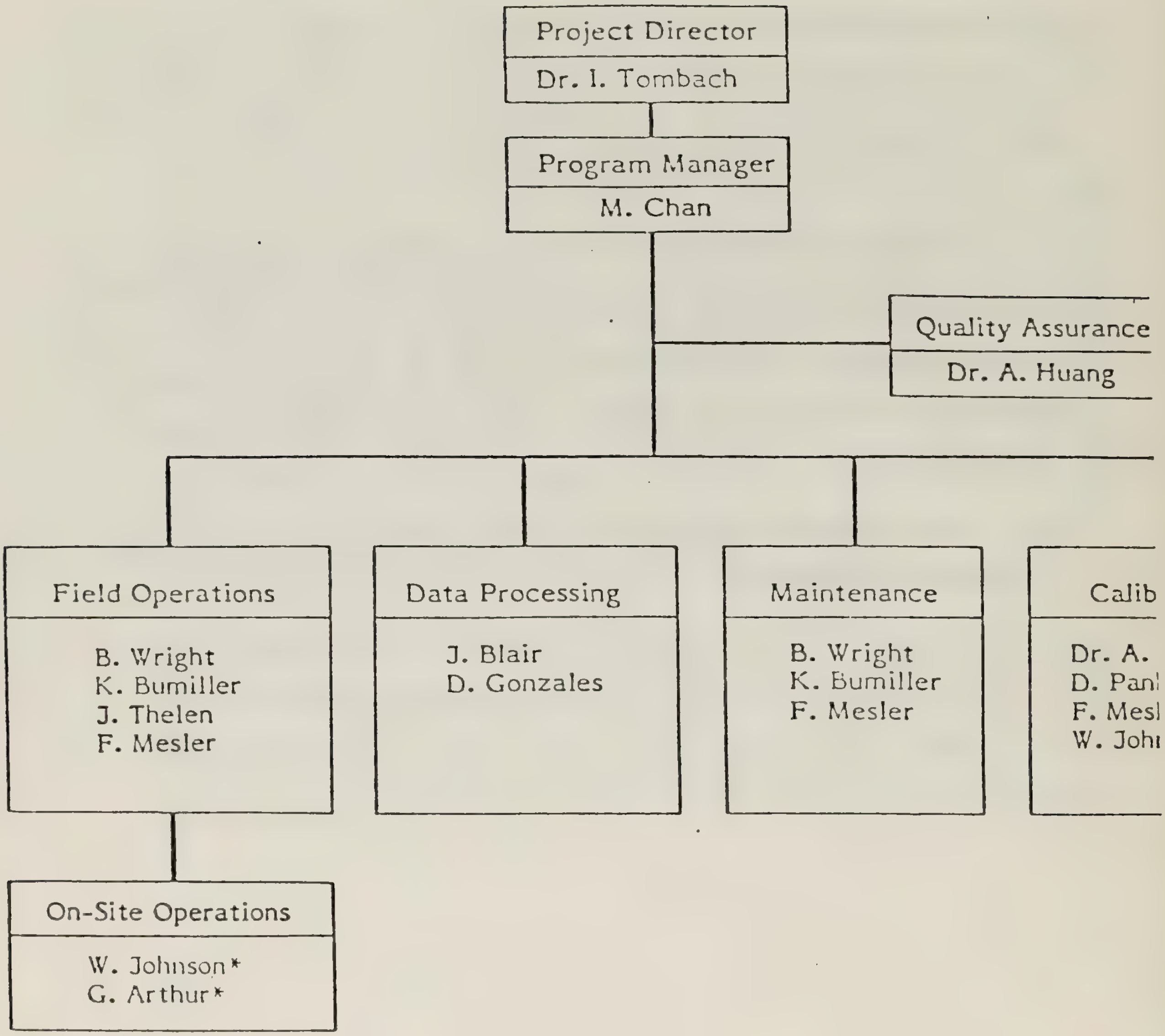
AeroVironment (AV) is responsible for the design, operation, maintenance and calibration of such a program, and for reduction of the data generated by the network. Day-by-day station checks will be conducted by Occidental Oil Shale, Inc. personnel following procedures established by AV.

2. ORGANIZATION AND RESPONSIBILITY

Corporate level management for AeroVironment's activities on the C-b Tract is provided by Dr. Ivar Tombach, AeroVironment's Vice President, Environmental Programs. Technical and project management is the responsibility of Mr. Michael Chan, Manager of Air Quality Studies.

The quality assurance aspects of the project are supervised by Dr. Andrew Huang, who is in charge of calibration. Mr. Bruce Wright, Manager of Field Operations is responsible for the operation and maintenance of the monitoring equipment, and Mr. John Blair, Manager of Data Processing, for the data reduction. Daily station checks are performed by Occidental personnel.

An organization chart for the quality assurance portions of the project is presented in Figure 2-1.



*Occident Oil Shale, Inc. employee

FIGURE 2-1. Project quality assurance organization chart.

3. PROJECT QUALITY ASSURANCE PROGRAM

Quality assurance is an integral part of a project. In this section, detailed procedures for each quality assurance element considered essential to the project are presented.

3.1 Monitoring Site Selection

Monitoring site selection criteria included the following:

a) No obstructions between the potential sources and the monitoring points;

b) No interference from other local sources;

c) Potential maximum air pollution impact for future development; and

d) Representativeness of area-wide air quality and meteorology.

Potential air contaminant sources in the C-b tract have been documented in a publication entitled "Oil Shale Tract C-b Modifications to Detailed Development Plan," submitted by Ashland Oil, Inc., and Occidental Oil Shale, Inc. to the Area Oil Shale Supervisor in February 1977. The current monitoring network has been designed according to that document, taking into consideration the existing baseline monitoring network.

Figure 3-1 illustrates the monitoring sites selected. As indicated, there are four monitoring stations, Sites 020, 023, 042, and 056. A station operational schedule which includes the air quality and meteorological parameters involved is presented in Table 3-1.

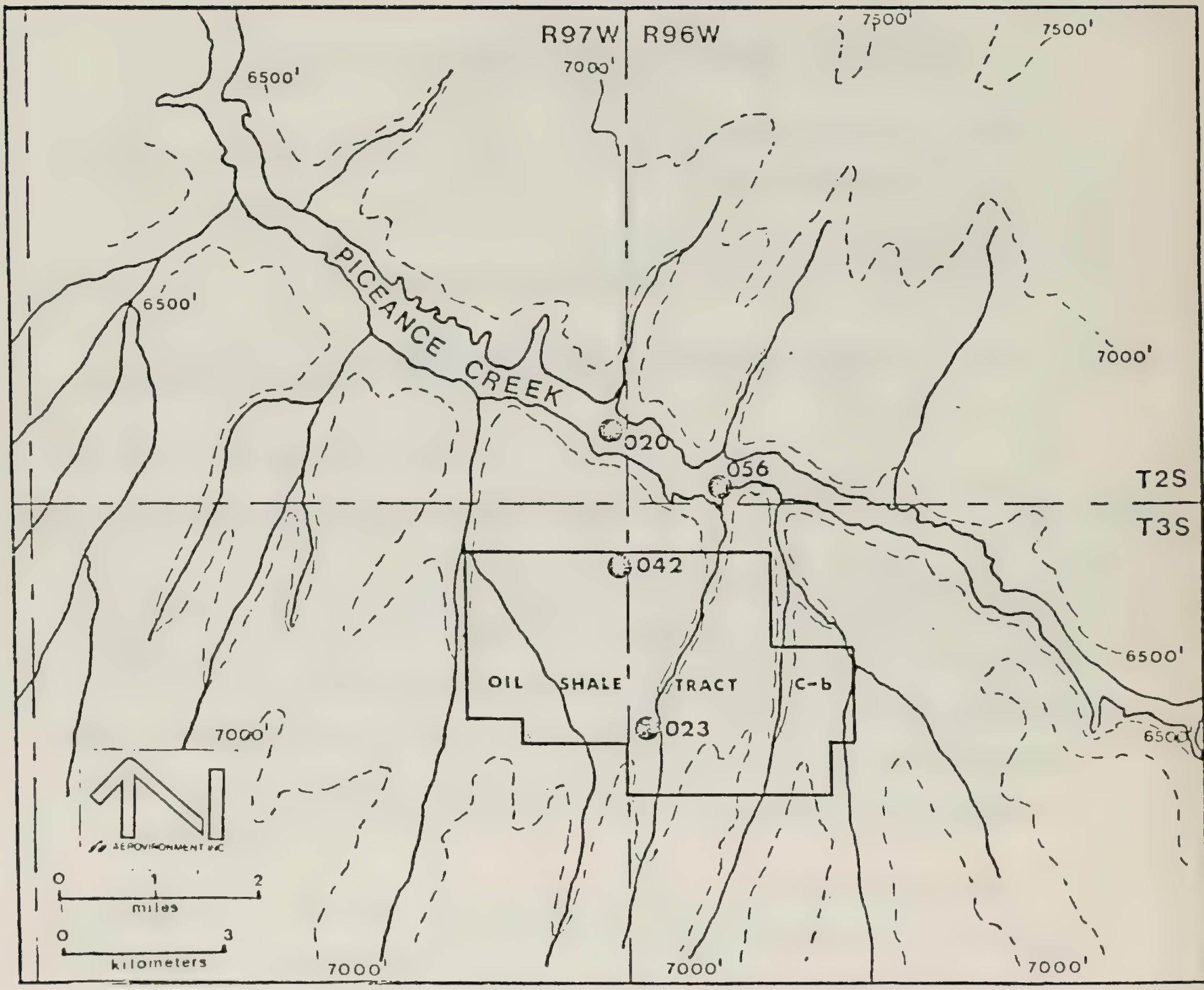


FIGURE 3-1. Air Quality and Meteorology Monitoring Locations

TABLE 3-1. Station Operational Schedule.

Site	Start-up Date	SO_2	H_2S	CO	O_3	$NO/NO_x/NO_2$	TSP	Met.	Mixing & Inversion Heights	Remarks
020	(a) 10/30/77							X		
	(b) 11/17/77								X	
	(c) 1/20/78						X			
	(d) 6/1/78			X	X	X				
	(e) 6/79	X	X							
023	Operational	X	X	X	X	X	X	X		60m Met. tower
042	(a) 1/13/78							X		
	(b) 2/1/78						X			
056	(a) 1/19/78							X		
	(b) 2/4/78						X			

3.2 Monitoring Equipment and Procedure

An amendment to Federal Register Section 51.17a "Air Quality Monitoring Methods" (Federal Register, Vol. 41, No. 232, Wednesday, December 1, 1976) stated that:

> (2) Any analyzer for SO_2, CO, or photochemical oxidant purchased before February 18, 1976, may be used for purposes of 51.17 (a) up to and including February 18, 1980. Any analyzer for NO_2 purchased prior to 1 year after date of promulgation of these amendments may be used for purposes of 51.17(a) for a period not to exceed three years after date of promulgation of these amendments. "

Therefore, for the on-going Cb project, it is required by the EPA that the monitoring instruments for SO_2, CO, and O_3 be converted to the instruments which EPA designates as reference or equivalent methods by February 18, 1980. The equivalent date for instruments for NO_2 is December 1, 1979.

Accordingly, AeroVironment utilizes the presently existing equipment as much as possible and, as appropriate, plans to convert the equipment in order to comply with the rules and regulations set forth by the EPA. Table 3-2 presents a list of equipment being used or to be used at the four different monitoring sites. Manufacturers' specifications are included in Appendix A.

All of the parameters of interest are monitored continuously except for TSP, which is measured at three-day intervals. The output from the instruments will be recorded by use of a Monitor Labs Model 9300 data acquisition system and backed up by an Esterline Angus Model E1124 E multipoint chart recorder at each of the 020, and 023 sites. At present, only EA multipoint chart recorders are used as primary recording means.

Data will be scanned using the data acquisition system at 10-second intervals. The 5-minute averages or 5-minute average r.m.s. values as calculated from the scanned data are then recorded on magnetic tapes. The

TABLE 3-2. Monitoring Equipment List.

Site	Parameter	Instrument	Principle of Operation	EPA Designated Instrument
020	SO_2	Meloy SA 185-2 w/H_2S scrubber	FPD	No
(10 m tower)	H_2S	Meloy SA 185-2 w/SO_x scrubber	FPD	NA
	THC/CH_4	Bendix 8200	GC-FID	NA
	CO	Bendix 8200	GC-FID	No
	O_3	Meloy OA 350-2	Chemiluminescent	No
	$NO/NO_x/NO_2$	Monitor Labs 8440E	Chemiluminescent	Yes
	TSP	General Metal Works GMWL-2000H	Hi-Vol Sampling	NA
	Wind speed/wind direction	WeatherMeasure W 1034	-	-
	Temperature	WeatherMeasure T621-TP18X	-	-
	Mixing height, inversion height	AeroVironment 300A	Acoustic radar	-

TABLE 3-2. (continued)

Site	Parameter	Instrument	Principle of Operation	EPA Designated Instrument
023	SO_2	Meloy SA 185-2A	FPD	Yes
(60 m tower)	H_2S	Meloy SA 185-2 with SO_x scrubber	FPD	NA
	CO	Bendix 8200	GC-FID	No
	O_3	Meloy OA 350-2	Chemiluminescent	No
	$NO/NO_x/NO_2$	Monitor Labs 8440E	Chemiluminescent	Yes
	TSP	General Metal Works 2000H	Hi-Vol Sampling	NA
	Wind speed/wind direction at 10m, 30m, and 60m	MRI 1074-2	-	-
	Temperature at 10m, 30m, and 60m	MRI 840	-	-
	Delta temperature 10m-60m	MRI 840	-	-
	σ_θ at 10m and 60m	MRI 1074-2 and Sigma Processor	-	-
	σ_w at 10m and 60m	R. M. Young 27103 Gill Anemometer	-	-
	Relative Humidity at ~1.5m	WeatherMeasure H324-S	Hair Hygrograph	-

TABLE 3-2. (continued)

Site	Parameter	Instrument	Principle of Operation	EPA Designated Instrument
023 (continued)	Barometric pressure	WeatherMeasure B 242	-	-
	Solar radiation	Eppley Spectral Pyranometer	-	-
042	TSP	General Metal Works 2000H	Hi-Vol Sampling	NA
	Wind speed/wind direction	MRI 1071	-	-
	Temperature	MRI 1071	-	-
056	TSP	General Metal Works 2000H	Hi-Vol Sampling	NA
	Wind speed/wind direction	MRI 1071	-	-
	Temperature	MRI 1071	-	-

5-minute and/or scanned values can be printed in tabular form on a printer on demand at each of these stations. The back-up EA chart recorder logs data at 2-1/2-minute intervals. At Sites 042 and 056, integral strip chart recorders are used to monitor the meteorological parameters. As for TSP, a Dickon recorder is used to record the high volume sampling flow rate throughout the 24-hour sampling period.

An environmentally controlled shelter is provided at Sites 020, and 023 to meet the instrument manufacturers' requirements. The equipment used at Sites 042 and 056 requires no environmental control.

3.3 Data Reporting

Data collected on magnetic tapes and strip charts will be reduced to obtain hourly averages of all parameters. One-hour statistical description of wind and turbulence will also be calculated. Calibration factors obtained during calibrations are then applied to arrive at final data.

AeroVironment will provide computer-printed tables of hour-by-hour averages for each month, except for TSP which will be given for 24-hour sampling periods.

o Raw Data Reduction Procedure

Data gathered on the magnetic tapes is compiled by computer to arrive at hourly averages of the parameters of interest. In the case of strip charts, in general the data is manually digitized, using a computer digitizer, to obtain hourly averages. In a few cases, manual strip chart reduction procedures will be used. The raw data thus derived are recorded on magnetic tape and are printed on appropriate data forms, together with other information on instrument status, such as times of calibration, maintenance, instrument malfunction, etc. Pertinent sections of AeroVironment's data reduction procedure are included in Appendix B.

o Data Calculation Procedure

The zero and span sources whose values are determined at the monthly multipoint calibration (see Section 3.5) are fed into the respective instruments daily, and the instrument responses recorded. The calibration factors are calculated based on these data, and they are applied to the monitored data for the next 24 hours or until the next zero and span checks occur. This approach insures that the instrument drift problems are adjusted on a daily basis.

Occasionally the instrument zero and span checks would give values which exceed control limits established (see Section 3.6 and Appendix E). This might be caused by excessive instrument drifts and/or unstable calibration sources. (In this case, the instruments will have to be readjusted or calibration sources replaced as soon as this kind of problem is detected during a daily station check.) The concept of extending one set of calibration factors over the next 24 hours would not give correct data. Under these circumstances, the data from the computer output is further calibrated by AV by use of the linear interpolation of the two sets of calibration factors over the intervals concerned. The calculations are handled by the AV in-house computer.

3.4 Data Validation

As noted before, the data system logs data once each five minutes, giving 12 values per hour. An hour of data is considered valid if it includes six 5-minute periods; i.e. this allows 6 values to define an hour. Strip chart data is considered to represent the hour if more than 30-minutes of the record is valid.

Data collected in the first 15 minutes after calibration is generally discarded. Data is considered erroneous if any of the status indications or the station log suggest instrument malfunctioning. In addition, air quality data collected in the first 15 minutes after a brief power outage (less than 10 minutes), in the first hour after a medium duration outage (up to one

hour), or in the first four hours after longer outages, will be discarded as unreliable. Any anomalous data reflecting signal spikes or dropouts with a response rate faster than ascribable to atmospheric phenomena (e.g., a tripling of NO_x levels from one scan to the next, followed by a return to the old level on the succeeding scan) will be deleted as an artifice caused by the system.

As an additional check, the calibrated data is also screened manually. First, data is scanned to detect extreme values. When a spurious value is located, it will be checked for its validity. In all cases when invalidated data is deleted, a record of these deletions is maintained. Only the validated data is reported.

3.5 Calibration

Monthly multipoint calibrations of all air quality instruments are performed. Calibration of air quality instruments was carried out at the start of the project, and monthly thereafter by AV. The purpose of the monthly calibration is two-fold: 1) to check the instrument linearity and, 2) to assign the values of the on-site calibration sources so that they are NBS traceable. For meteorological equipment, off-site calibration was done in the first three months, and calibration checks are performed quarterly thereafter by AV. Table 3-3 presents the schedule for calibrations.

- Methodology

The air quality instruments for SO_2, H_2S, O_3, and NO/NO_x will by dynamically calibrated by use of a Monitor Labs Model 8500 Dynamic Calibration System. This calibrator utilizes the permeation principle for SO_2 and H_2S, ozonation of air for ozone, and dilution of concentrated NO to ambient level NO, and can perform gas phase titration of NO and O_3 for NO_2 calibrations. It is capable of producing stable concentrations for the purpose of calibration of the instruments. For the CO instruments, three cylinders of gases containing approximately 0, 4, and 8 ppm of CO are used to calibrate the analyzers.

Instrument linearity will be established by multi-point calibration. AV calibration record forms are included in Appendix C.

The calibrator's SO_2 permeation tube output is calibrated quarterly by using the EPA-prescribed pararosaniline method (Federal Register, Vol. 36, No. 84, Part II, April 30, 1971); H_2S output by the cadmium hydroxide stractan method (Intersociety Committee, American Public Health Association, Washington, D.C., 1972); and O_3 output by the EPA prescribed 1% neutral buffered potassium iodide (NBKI) method (Federal Register, ibid). The concentrated NO cylinder used (~100 ppm) is NBS traceable, and the traceability is maintained by re-analyzing the cylinder once every six months by using an NBS cylinder. The dilution system of the calibrator is checked once every three months by using an NBS traceable test meter. The NO dilution output from the calibrator is further calibrated quarterly by use of the Saltzman method (Intersociety Committee, ibid).

Cylinders used to calibrate the CO instrument are NBS traceable. The traceability is maintained by re-analyzing the cylinders once every six months by using an NBS cylinder.

The high volume sampler is calibrated monthly by use of a set of resistance plates which in turn, is calibrated by using an NBS traceable Roots Meter once a year. The balance used for weighing glass fiber filters is calibrated quarterly by using a set of NBS traceable weights.

Consistency checks are made for all the calibration results on the AV transfer standards, namely the Monitor Labs Calibration System and CO cylinders. The emphasis of the quality assurance program is to establish an unbroken chain of traceability of the reported data to the EPA reference methods or NBS standards.

Calibration of some of the meteorological equipment is done off-site as indicated in Table 3-3. Detailed calibration schedule is presented in Table 3-4. The wind sensors are calibrated by use of an NBS traceable wind tunnel, the temperature sensors by use of an NBS traceable thermometer,

TABLE 3-3. Calibration and maintenance schedule.

	1977			1978								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Air Quality Instruments												
AV Calib. & Maintenance	▲			▲			▲			▲		▲
Field Operator calibration & Maintenance		▲	▲		▲	▲		▲	▲		▲	▲
Meteorological Instruments												
Off-site Calibration							◄	—	—	—	►	
Calibration Check and maintenance				▲			▲			▲		▲
Calibration System												
AV Calibration	▲			▲			▲			▲		▲
Analytical Balance												
AV Calibration	▲			▲			▲			▲		▲

TABLE 3-4. Meteorological Equipment Calibration Schedule

Site	Parameter	Instrument	Month, 1978				
			Apr	May	Jun	Jul	Aug
020	WS/WD	Weathermeasure W1034					
	T	WeatherMeasure T621-TP18X					
023	WS/WD at 10m	MRI 1074-2					
	WS/WD at 30m	MRI 1074-2					
	WS/WD at 60m	MRI 1074-2					
	T at 10m	MRI 840					
	T at 30m	MRI 840					
	T at 60m	MRI 840					
	ΔT (60m–10)m)	MRI 840					
	σ_w at 10m	R.M. Young 27103 Gill Propeller Anemometer					
	σ_w at 60m	R.M. Young 27103 Gill Propeller Anemometer					
	σ_θ at 10m	MRI 1074-2					
	σ_θ at 30m	MRI 1074-2					
	σ_θ at 60m	MRI 1074-2					
	Relative Humidity	WeatherMeasure H324-S	Not needed since it is checked by a sling psychromater daily				
	Barometric pressure	WeatherMeasure B242	Not needed since it is checked by a barometer daily				
	Solar radiation	Eppley Precision Spectral Pyranometer					
042	WS/WD	MRI 1071	Not needed since it is newly installed				
	T	MRI 1071					
056	WS/WD	MRI 1071	Not needed since it is newly installed				
	T	MRI 1071					

and the pressure sensors by use of an NBS traceable barometer. The accuracy of the methods will be traceable to NBS standards when applicable.

3.6 Station Check

Station checks are performed daily by the C-b Shale Oil Venture personnel following the procedure established by AV and using the Daily Check List form, as provided in Appendix D. The main concerns here are to insure that the analyzers and the supporting equipment are in proper working condition.

Zero and span are checked for the analyzers during the station check. For SO_2, H_2S, O_3, and NO/NO_x instruments, this is accomplished by use of the on-site Meloy RAD-1 calibrators which operate on the same principle as the Monitor Labs 8500 (Section 3.5) except that they produce only one concentration for each of SO_2, O_3 and NO. (H_2S analyzer is checked by input of SO_2). For CO, a hydrocarbon-free air cylinder and a span cylinder containing approximately 8 ppm of CO are used.

The zero and span values for each instrument will be used to create control charts, guidelines for which have been described ("Quality Assurance Handbook for Air Pollution Measurement Systems, Vol. 1 – Principles," EPA-600/9-76-005, 1976). The control charts will be a useful tool to detect early instrumental problems. Appendix E gives the AV Control Chart form.

Any instrument problems are reported by the station check personnel to AV on the same day so that corrective action can be initiated as soon as possible. In addition, an instrument station report is provided weekly by the station check personnel to AV. Appendix F shows the AV instrument status report form.

3.7 Preventive Maintenance

Maintenance procedures and schedules are in accordance with the manufacturer's instructions and AeroVironment's experience with the

instruments. A schedule for routine maintenance required to insure proper data collection by the instruments is shown in Table 3-5. Major preventive maintenance is performed quarterly as shown in Table 3-3.

3.8 Audits/Interlaboratory Tests

This project will continue to participate in the Western Energy Quality Assurance Program sponsored by EPA to establish data credibility. The frequency of this audit is approximately once every three months. A report is provided by the EPA after each audit. Should a discrepancy exist which warrants further investigation, it will be so recommended in order to resolve the differences.

AeroVironment participates in various continuing interlaboratory comparison programs, as part of its own internal QA program. Of particular interest here is AV involvement in the Ambient Sulfur Dioxide Cross Reference and Atmospheric Air Monitoring Cross Reference Services of Scott Environmental Technology, Inc., Plumsteadville, Pennsylvania. The C-b project benefits from this, since the calibrations of all AV operated programs are cross-correlated with each other at all times.

3.9 Spare Provisions Policy

For the air quality instruments, it will be a goal that a back-up instrument be available for each of the significant air quality parameters measured. The back-up instrument is to be in working condition at all times so that it can replace a like malfunctioning instrument, or a circuit card or component can be removed from it to repair an on-site instrument. The resulting non-operating instrument can then be repaired at a more leisurely pace, without the pressure of loss of data. An additional stock of certain key parts, such as pumps, valves, motors, and lamps, will also be maintained. The meteorological equipment requires spare parts, such as wind cups, wind vanes, and circuit cards. Complete spare systems usually are not needed here. In addition, spares for the calibration systems, balances, and data acquisition systems will be maintained. Table 3-6 is a list of recommended spare parts to be maintained.

TABLE 3-5. Instrumentation check and preventive service intervals

Interval	Service
Daily	Check span, zero and flows for all analyzers; adjust and recalibrate if necessary Check relative humidity and barometric pressure readings Check data system clock date and time; reset if necessary
2 weeks	Change membrane filter on O_3 analyzer sample line
1 month	Change membrane filter on NO/NO_x and GC analyzer sample lines
3 months	Replace glass wool in sample cane Replace hi-vol sampler motor brushes Reset data system attenuators and correlate with analyzer meters Check operation of anemometers and alignment of vanes Check calibration of temperature and ΔT sensors
6 months	Clean and vacuum test sampling manifold Inspect pump diaphragms in analyzers; replace if necessary

TABLE 3-6. Recommended Equipment Spare Parts

Equipment	Spare Part Description	Part No.	Quantity
	Air Quality		
Meloy SA 185-2A Sulfur Analyzer	Complete analyzer	--	1
	Flow capillary	S 900113	6
	Hydrogen regulator	S 900425	4
	Septum	S 90023	8
	Dilution orifice	S 90024	8
	Sample pump	S 900016	4
	Optical window	S 20066	8
	Heat shield window	S 900121	8
	H_2S scrubber	S 001072	2
	SO_x-2 scrubber	N/A	2
	Gelman charcoal filter	N/A	8
Bendix 8200 Environmental Chromatograph	Complete analyzer	--	1
Meloy OA350-2 Ozone Analyzer	Complete analyzer	--	1
	Amplifier	S 200197	1
	Critical orifice assembly	S 000609	1
	Sample pump	S 900089	1
	Dilution air orifice	S 900229	5
	Dilution air septum	S 900230	1
Monitor Labs 8440E NO/NO_x Analyzer	Complete analyzer	--	1
	Mixer board assembly	84000083	1
	Chopper motor and capacitor	2588	1
	Drive belt	2-049	10
	Drive belt	2-042	10
	Charcoal scrubber	12001	10
	Pump diaphragm	8060814S	10
	Sample pump	N/A	1
GMWL-2000H Hi-Vol Sampler	Motor	N/A	1
	Motor Brush	N/A	2
	Transformer	N/A	1
	Complete sampler	--	1

TABLE 3-6. (continued)

Equipment	Spare Part Description	Part No.	Quantity
	Meteorological		
WeatherMeasure W1034 Wind Sensor	Complete system	--	1
	Wind cup	Type 3L	1
	Wind vane	W104-V	1
MRI 1074-2 Wind Sensor	Complete 1074 head	1074-2	1
	Wind cup	N/A	1
	Wind vane	N/A	1
	Wind speed tach card	12905	1
	540° azimuth card	14303	1
WeatherMeasure T621-TP18X Temperature Sensor	Complete system	--	1
MRI 840 Temperature and ΔT system	MRI 840-1	N/A	1
	Temperature amplifier card	13495	1
	MRI 840 series ΔT probe set	N/A	1
	ΔT amplifier card	17090-1	1
R.M. Young 27103 Prop. Anemometer	Complete set	--	1
R.M. Young 21003 Prop. Bivane	Complete set	--	1
MRI 1071 Mechanical Weather Station	Complete set	--	1
WeatherMeasure H324-S Hair Hygrograph	Hair bundle	H324-HB	1
AV 300A Acoustic Radar	Basic spare parts kit	--	1

3.10 Training

Permanent on-site personnel consists of a station operator and an instrument technician, both of whom are employees of the C-b Shale Oil Venture. AeroVironment is responsible for the training of these individuals. In general, training will be provided in the following areas:

- Station operation and checking
- Instrument maintenance
- Instrument repair
- Instrument calibration
- Record keeping
- Data reduction
- Minisonde and theodolite operation.

The training approaches vary from one area to the next, and include:

- Formal classroom training on equipment servicing, by manufacturers of equipment used on the tract.
- On-the-job training, while working in parallel with the AV staff.
- On-site instruction and practice, with AV technical staff as instructors, in such areas as station checks, instrument calibration, and minisonde launching.

The AeroVironment staff involved with the project is familiar with all aspects of air monitoring system operation, and will itself require no further

training except for familiarization with some of the specific models of instruments used on the C-b tract.

3.11 Others

o Hi-vol filter weighing procedure:

1. Filters should be inspected against light for pinholes; discard the ones with pinholes.

2. Install filters in a drying cabinet for at least 24 hours to condition. Make sure that the desiccant (Drierite) inside the cabinet is still good (i.g., blue color).

3. Weighing is done only when the laboratory relative humidity is less than 50%. First, the balance is set to 0.0000 when there is no load. A one-point check, nominally at 5 g., is then carried out to ascertain that the balance is still good.

4. Proceed to weigh all the blank filters conditioned. Each weighed blank filter is then installed unfolded in an envelope with a label recording the blank filter weight. Install the envelope containing a blank filter in the drying cabinet to be ready for use.

5. Exposed filters should be folded into one-half (exposed surface inward) and conditioned as indicated in step 2. Proceed the weighing of the exposed filters by following step 3 first.

6. Exposed filter weight is recorded on the same label as the blank filter weight so that the net weight can be derived by subtraction.

7. 10% re-weighing of the blank and exposed filters is required for internal quality assurance pruposes.

4. DISTRIBUTION LIST

C-b Shale Oil Venture

Mr. Robert Thomason
Dr. George Fosdick
Mr. Bill Johnson
Mr. G. D. (Art) Arthur
Mr. Spencer Bullard
Mr. Charles Bray

Area Oil Shale Supervisor's Office

2 copies - Attn: Mr. Miles LaHue

EPA Region VIII

2 copies - Attn: Mr. Terry Thoem

Colorado Department of Health, APCD

2 copies - Attn: Mr. Scott Miller

AeroVironment Inc.

Mr. Michael Chan
Dr. Andrew Huang
Mr. Bruce Wright
Mr. John Blair
Mr. Kurt Bumiller
Mr. Floyd Mesler

APPENDIX A

Equipment Specifications

SPECIFICATIONS
MELOY SA 185-2A SULFUR DIOXIDE ANALYZER

Note: Use of this analyzer under EPA designation as a an Equivalent Method requires operation on the 0.5 ppm full scale range within a temperature range of 20-30°C and line voltage range of 105 to 125VAC.

Analyzer Performance Specifications*

Range:		0-0.5 ppm
Noise (RMS)	0% URL:	.002 ppm
	80% URL:	.003 ppm
Minimum Detectable Limit:		0.004 ppm
Interference Equivalent:		± 0.02 ppm each interferent Max. 0.06 ppm Total interferent Max.
Zero Drift: (12 and 24 hrs):		± 0.005 ppm
Span Drift: (24 hr.)	20% of URL:	± 10% Max.
	80% of URL:	± 5% Max.
Lag Time:		10 seconds max.
Rise Time (95%)		3 minutes max.
Fall Time (95%)		3 minutes max.
Precision:	20% of URL:	.005 ppm
	80% of URL:	.005 ppm
Linearity:	a) With Linearizer Output (Option S-1)	±1% Full Scale
	b) Without Linearizer Output (Log-Linear Output)	±1% Full Scale

*The definition and the method of determination of these specifications are given in 40 CFR 53 and the Federal Register, Volume 40, Number 33, Part II, "Ambient Air Monitoring Reference and Equivalent Methods", (40 FR, p. 7044, February 18, 1975).

Analyzer Operational Specifications

Unattended Operation: (No adjustment of flow or electrical systems)	7 days
Sample Flow Rate:	Approx. 200 ml/min
Hydrogen Flow Rate:	Approx. 125 ml/min
Outputs: (Linear with Option S-1; Log-linear without option)	a) Meter: 0-0.5 ppm b) Recorder: 0-100 mv 0-1 V
Relative Humidity Range:	0-95%
Ambient Temperature Range:	20 to 30°C (EPA approved), 10-40°C*
Voltage Range:	115 ±10 VAC, 60 Hz
Power Requirements:	250 Watts

Analyzer Configuration Specifications

Weight:	40 to 50 lbs (18 to 22 Kg) depending on options included
Case Dimentions:	17" (43.2 cm)W x 20" (50.8 cm)L x 12 1/4" (31.1 cm)H
Mountings Available:	a) Bench b) Rack (optional), 19"(48 cm) wide
Sample Pump:	Internal

**Use of this analyzer under EPA designation as a reference method requires operation within a temperature range of 20 to 30°C and 105 to 125 VAC. However, the analyzer will operate over 10 to 40°C with only a small increase in the noise, precision, and drift specifications stated.

H_2S SCRUBBER SPECIFICATIONS

Life:	a. In excess of 9000 hours at typical ambient H_2S level of 5 ppb.
	b. In excess of 450 hours for H_2S concentration levels not exceeding 0.1 ppm.
Scrubbing Efficiency:	98% H_2S while passing 98% or greater SO_2.
Sample Lines	1/8" (3.175 mm) OD Teflon Tubing
Size:	4" (10 cm) long x .625" (1.6 cm) diameter

SPECIFICATIONS
MELOY SO_x-2 SCRUBBER TO MODIFY SA 185-2 FOR USE AS AN H_2S ANALYZER

The SO_x-2 Scrubber is an accessory unit designed specifically to be utilized with Meloy Sulfur Analyzers. This scrubber removes Oxides of Sulfur to allow the FPD Analyzer to measure total reduced sulfurs such as H_2S, CS_2, Mercaptans, etc.

SPECIFICATIONS
BENDIX 8200 ENVIRONMENTAL CHROMATOGRAPH

Ranges:	Stepwise attenuation for each component with 1, 2, 5, 10, 20, 50 and 100 sequence. Basic range selectable from 0-1 ppm to 0-100 ppm.
Precision:	±1% of full scale.
Noise Level:	0.5% of full scale.
Zero Drift:	Less than ±1% per day and ±2% for three days with automatic zero before each component.
Span Drift:	Less than ±1% per day and ±2% for three days.
Interference Equivalent:	Less than 1 ppm.
Linearity:	Better than 2% of full scale.
Oven Temperature:	Controlled to ±0.5°C.
Cycle Time:	Five minutes.
Operational Period:	More than 3 days unattended.
Output Signal:	Trend outputs of 0-1 volt or 1-5, 4-20, or 10-50 madc at 12 volts for each component. Other voltages available.
Readout:	Chromatogram and trend.
Power:	115 vac, 60 Hz.

SPECIFICATIONS

MELOY OA 350-2 OZONE ANALYZER

Performance Specifications

Range:	0 to .01 ppm 0 to .1 ppm 0 to .5 ppm 0 to 1.0 ppm 0 to 5.0 ppm 0 to 10.0 ppm
Minimum Detectable Sensitivity:	0.0005 ppm
Noise:	±0.3% on 0.5 ppm scale
Lag Time:	less than 10 sec.
Rise Time (95%)	less than 15 sec.
Fall Time (95%)	less than 15 sec.
Precision:	±2% F.S.
Zero Drift:	±1% F.S. per day on 0.5 ppm scale ±2% F.S. per day on 0.01 ppm scale ±2% F.S. per 3 days on 0.5 ppm scale
Span Drift:	less than ±1% per day on 0.5 ppm scale less than ±2% per 3 days on 0.5 ppm scal
Linearity:	±1% F.S.

Operational Specifications

Unattended Operation: (No adjustment of flow or electrical systems)	7 days
Sample Flow Rate:	Approximately 500 ml/min

Ethylene Flow Rate:	Approximately 30 ml/min
Power Requirement:	115 VAC, 50-60 Hz, 250 Watts
Outputs:	(a) Meter: 0-10 ppm (b) Recorder: 0-100 mv and 0-1 volt
Relative Humidity Range	10 to 95%
Ambient Temperature Range:	10-40°C for specified specifications

Configuration Specifications

Weight:	Approximately 40 lbs
Case Dimension:	19" W x 20" L x 12 1/4" H
Mounting Available:	(a) Bench (Standard) (b) Rack (Optional)
Sample Pump:	Internal

SPECIFICATIONS

Zero Instability:	Less than 0.1% full scale/mo., ±3°C from set temperature 0.025%/°C over the range 25°C ±20°C
Span Stability:	Less than ±1%/day span drift from all sources ±5°C from cal. temp. Less than ±2% span drift/14 days ±5°C from cal. temp. Maximum temperature coefficient of span 0.2%/°C over the range 25°C ±20°C
Lag Time:	Less than 3 sec. from step change at input
Repeatability:	±1% NO and NOx output ±1.4% NO_2 output
Operating Temperature:	0°C to +50°C
Detection Limit:	2ppb for NO, NO_2, NO_x
Measuring Ranges:	0.2, 0.5, 1.0, 2.0 and 5.0 ppm full scale (ranges to 5000 ppm available)
Response Time:	1.0 sec., 5 sec., 20 sec., 1 min, nominal, switch selectable

Settling Times % of final answer

Range	63.5%	90%	99%
1	1 sec.	2.3 sec.	4.6 sec.
2	5 sec.	11.5 sec.	23 sec.
3	20 sec.	46 sec.	92 sec.
4	1 min.	2.3 min	4.6 min.

SIGNAL OUTPUTS	Recorder:	0-100mv-zero adjustable ±5mv, up scale adjustable ±20% 0-1v, 0-2v, 0-5v, 0-10v optional
	DVM:	0-2v, 0-1v, 0-.1v, 0-5v, 0-10v optional Output impedance less than 2.5K ohms
	Meter Jack:	Front Panel 0-1v, adjustable, 10-turn calibrated pot
	Connector:	Terminal Strip
STATUS OUT (OPTIONAL)	Range:	One of 5 transistor buffered (open collector
	Time Constant:	One of 4 transistor buffered outputs
	Function:	Transistor-buffered, closure
	Warning:	Transistor-buffered, closure
	Power Failure:	No Closure on range or status
	Connector:	ML 005C0001 supplied
FLOW RATES	Sample:	500 cc/min. each channel nominal
	Ozone:	80 cc/min. each channel nominal

Support Gas Required:	Ambient Air
Sample Line Material:	Stainless Steel and Teflon
Power:	115VAC 50/60 HZ
Weight:	32 kg (70 lbs)
Dimensions:	2 modules each 22.2 cm (8 3/4") high, 48.3 cm (17") wide, 44.1 cm (17") deep May be stacked, set side by side or rack mounted.

SPECIFICATIONS

MODEL GMWL-2000 H

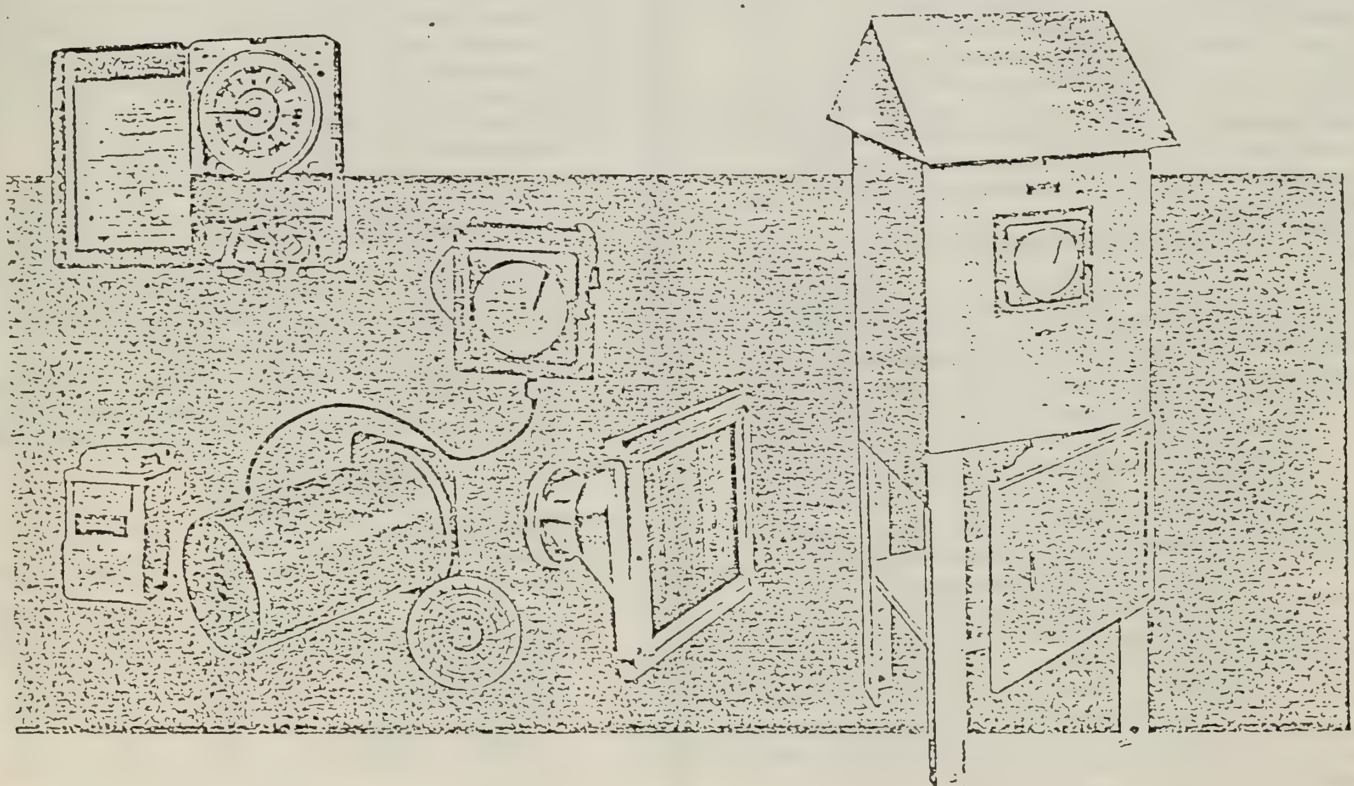
High Volume Air Sampler

Designed for continuous operation in an all weather environment, the Model GMWL-2000 H is a complete monitoring station for the collection of suspended particulate matter with precise measurement capability. All instruments and components are mounted within the aluminum shelter for complete protection. The hinged roof facilitates filter media exchange.

The Model GMWL-2000 H is complete with high volume sampler, seamless stainless steel filter holder, pressure transducer recorder, 50 charts, ink and 90-volt protective transformer all housed in the aluminum shelter ready to operate. A seven day regular timer Model GMW-70 is included as standard equipment. The timer/programmer Model GMW-80 is optional.

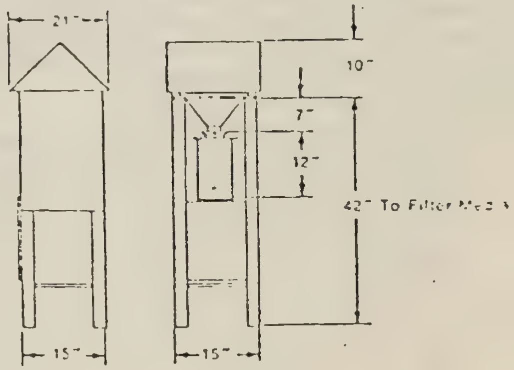
The sampler is a heavy duty turbine type blower with high speed motor arranged with a fixed orifice on the discharge end. Although factory calibrated against a water manometer, recalibration is suggested to suit barometric conditions at the site. Air flow is accurately measured by the pressure transducer which provides a permanent record of every sample.

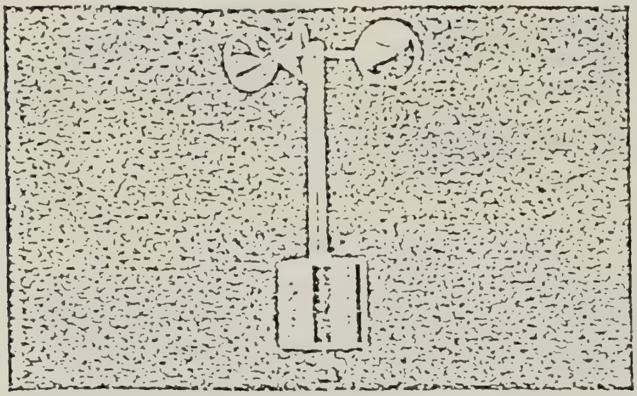
Four bolts, easily accessible, permit motor removal for periodic brush replacement. Special U-clip connectors facilitate brush changing and prevent damage to the internal leads. The 90-volt transformer reduces the operating voltage to approximately triple normal brush and motor life.



Specifications:

Motor HP — 0.6
Speed — 13,500 R.P.M.
Amperage — 4.9
Wattage — 440
Max. Flow Rate — 52 C.F.M.
Min. Flow Rate — 20 C.F.M.
Power Source — 115 V, 1 phase, 60 Hertz (other electrical characteristics available on request)
Net Weight — 63 lbs.
Shipping Weight — 70 lbs.
Meets all Federal performance and dimensional specifications including Federal Register Vol. 36, No. 84 dated April 30, 1971





Model W103 Cup Anemometer

DESCRIPTION

A high response, low threshold wind system which offers the optimum in versatility and economy. Design features of the cup anemometer and single fin aerodynamic vane permit a choice of sensor options to meet program needs and budgetary requirements. Electronic signal conditioning packages are available for any combination of sensor options. Anemometer and vane housings are cast from a special aluminum alloy and are aged before machining. Surfaces are anodized after machining. Sealed and shielded stainless steel permanently lubricated bearings and stainless steel precision ground shafts are used exclusively. Cannon connectors, mounted on the base of the housing, support the sensors as well as providing for electrical connection. Thus, after initial installation, sensors can be removed for routine maintenance by simply uncoupling the Cannon connector. Brass housings are available as an option for use in extremely corrosive marine environments.

Basic components of the W1034 Low Threshold Wind System are:

a. Model W103 Lightweight Cup Anemometer, with high frequency frictionless tachometer or DC generator.
b. Model W104 Lightweight Vane, with single or dual wipers.
c. Model WT1034/360-(x) or WT1034/540-(x) Translators.
d. Model W101-DGO, Two Pen, Dual Channel Galvanometric Strip Chart Recorder (DC only) or Model REW 2P-12V/12V, two pen, potentiometric strip chart recorder for AC operation.

Descriptions and specifications for the various options of each of the basic components of the system are given below.

Model W103 Cup Anemometer

Options available with the Model W103 Cup Anemometer include 5 different cup assemblies and 2 types of speed transducers. Cup assemblies can be 3 cup or staggered 6 cup. Three-cup assemblies are supplied as standard and are best suited for most applications. Six-cup assemblies eliminate pulsing at low wind velocities. Material used in the construction of the cups includes lightweight metallized butyrate, standard weight polycarbonate, plastic or stainless steel. Transducers available are a frictionless high frequency tachometer providing a pulsed square wave output signal or, where maximum sensitivity is not required, a low torque DC generator.

a. Cup Assemblies – 3 Cup Type

1) "3L" Cup Assembly, Lightweight – For low threshold applications. Cups are formed from 0.010" thick metalized butyrate suspended on a tubular stainless steel frame. The cups are conical shaped with a 2" diameter. Turning radius of the assembly is 2¼". Wieght of an individual cup, including supporting frame, is 5 grams. Weight of the complete assembly, including the central hub, is 18 grams.

2) "3S" Cup Assembly, Standard Weight – For general purpose application. Molded of durable lexan plastic, 0.030" thick. Cup diameters are 3" and assembly turning radius is 3½". Complete cup assembly weight, including central hub, is 42 grams.

3) ... are made of 0.025" thick stainless steel. Turning radius of the assembly is 2¼". Weight of the assembly, including central hub, is 63 grams.

b. Cup Assemblies – 6 Cup Type (U.S. Pat. No. 3,541,8[illegible]). Eliminate pulsing and reduce errors due to non-horizontal wind flow.

1) "6L" Cup Assembly -- Staggered 6-cup assembly constructed of same material as "3L" cups. Weight of assembly is 37 grams.

2) "6SS" Cup Assembly -- Staggered 6-cup assembly constructed of stainless steel and similar to "3SS" assemblies. Weight of "6SS" cups is 128 grams.

c. Speed Transducers

1) High Frequency Tachometer – For low threshold applications, a unique frictionless tachometer employing a high frequency oscillator and receiver is used to precisely measure wind speed. The oscillator, transmitter and receiver are encapsulated in a small cube of epoxy for total protection against the environment. The transmitter and receiver are separated by a 1/8 inch space in which a thin notched disc of aluminum, attached to the sensor shaft, is free to rotate. As each notch in the disc passes between the transmitter and receiver, a ~12 volt square wave pulse is produced. Discs are notched to provide fourteen output pulses per revolution. An input of 12 volts DC, 10 mA is required to power the tachometer circuitry. The output pulse train is fed into a frequency to analog converter in the wind system translator to permit data recording or telemetry. The operating temperature range of the high frequency tachometer is –30° to +140°F.

The high frequency tachometer embodies several distinct advantages over the commonly used light chopper systems. There are no light bulbs or photocells to burn out; power consumption is low; and the system is insensitive to moisture condensation or dust deposition. The solid state tachometer is essentially free from maintenance with a life of well over five years when operated continuously.

2) DC Generator – Long life DC generators can be supplied where starting torque is not critical. Generators have a life of three to four years and have an approximate output of 500 mV at 50 MPH.

SPECIFICATIONS

W103 Cup Anemometer

- Size .... 16¾"h x 7"d overall
- Cup Assemblies

Type	Cup Diameter	Turning Radius	Weight (grams)
"3L" Lightweight	2"	3½"	18
"3S" Standard Weight	3"	4"	42
"3SS" Stainless Steel	2"	3½"	63
"6L" Lightweight, 6-cup	2"	3½"	37
"6SS" Stainless, 6-cup	2"	3½"	128

- Transducers

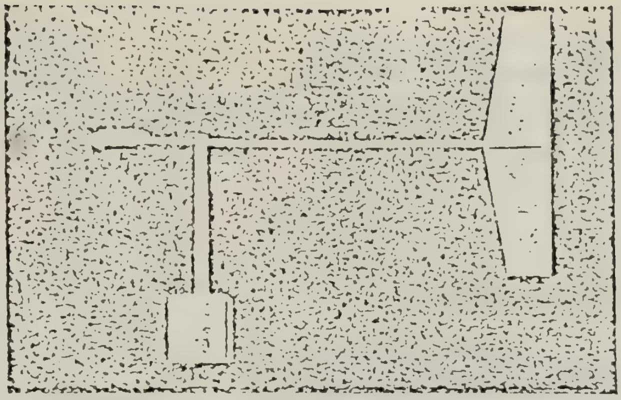
Frictionless High Frequency Tachometer – 12 VDC, 10 mA input. ~12 VDC square wave output; 14 pulses/RPM standard

DC Generator – Approx. 500 mVDC at 50 MPH

- Accuracy.................. ±1% or 0.15 MPH, whichever is greater
- Construction .... Anodized aluminum and stainless steel
- Bearings .... Sealed and shielded precision stainless steel
- Response Characteristics

High Frequency Tachometer Transducer	Threshold (MPH) 3-Cup	Threshold (MPH) 6-Cup	Distance Const. (Ft.) 3-Cup	Distance Const. (Ft.) 6-Cup
Model "L" Cups	0.6	0.6	5	7.3
Model "S" Cups	0.8	N/A	7.4	N/A
Model "SS" Cups	0.9	0.9	14.3	21.1

DC Generator Transducer	3-Cup	6-Cup	3-Cup	6-Cup
Model "L" Cups	1.0	1.0	[illegible]	[illegible]



Model W104 Light Weight Vane

The Model W104 Lightweight Vane features a special low density, high structural strength foam plastic tail coated with a high density epoxy and bonded to a stainless steel rod. Weight of the entire tail assembly, including rod, is 35 grams. A stainless steel counterbalance, located close to the center of rotation, permits maximum response to wind fluctuations with minimum overshoot. The tail has an airfoil shape. Tail dimensions are approximately 4" wide x 12" high x ¼" thick at the center and 1/8" thick at the tip. The center of the tail is normally located 12 inches from the axis of rotation.

The vane rotates on a stainless steel shaft mounted in miniature stainless steel precision bearings.

1000 ohm low torque potentiometers, supplied with one wiper for 0 to 360° applications and with two wipers for 0 to 540° systems, are standard. Other resistances are available on special order.

W104 Light Weight Vane

- Response Characteristics:

Wire Wound Pot	Dead Band (Degrees)	Damping Ratio	Distance Constant (ft)
1 wiper	3	0.4	~3.5
2 wipers	0	0.4	~3.5

- Threshold .... 0.75 mph
- Potentiometer Linearity .... 0.5% std., 0.25% special
- Resolution .... 0.72 degree
- Material .... Tail—plastic; housing—aluminum; shaft, bearings & counter balance —stainless steel
- Size .... Overall—21½"h x 21"l Tail—4"W x 12"H x ¼" Thick at center & 1/8" at tip; airfoil
- Weight .... Tail and supporting arm, 35 gms. Complete assembly, 1.6 lbs.

Translators

Stabilized power to operate the wind sensors; signal conditioning and ranging of the sensor outputs; and impedance matching to recording systems are provided by the Model WT1034 Translator. Translators are available with either 0 to 360° or 0 to 540° output range for wind direction. Ranges to 0 to 50 mph and 0 to 100 mph are normally provided for wind speed. Other ranges can be obtained on special order. Automatic range switching, with an event pen to indicate the range, is also available as an option.

All circuitry is solid state, employing the latest in integrated circuitry design. Linearity is ±0.1%. The units may be operated from either 12 VDC or 115 VAC, 50/60 Hz.

When purchased as a complete wind system, translators are built into the recorders. If sensors are to be used separately or with data logging or telemetry systems, separate enclosures for the translators are provided.

SPECIFICATIONS
METEOROLOGY RESEARCH 1074-2
WIND SENSOR

Specifications

The accuracies stated are "worst case" and represent the conditions where all components of the system are subjected to the full temperature range of −40°C to +50°C. Where the electronics portion of the system is in a less adverse temperature environment, improvements in accuracy up to 50% can be realized.

Wind Sensor 1074

Wind Speed

Starting Threshold	
Light Chopper and Switch Closure	0.75 mph
Generator	1.5 mph
Response Distance	18 ft. (63% Recovery)
Flow Coefficient	7.9 ft./Rev.
Accuracy	
Light Chopper and Switch Closure	±0.4 mph or 1% (whichever is greater)
Generator	±0.5 mph or 1% (whichever is greater)
Range	
Light Chopper	0-20, 0-80 or 0-100 mph
Generator	0-100 mph
Switch Closure	for each 1/10 Mile
Output	
Light Chopper and Generator Voltage	0 to +5 VDC
Impedance	<100 ohms
Operating Temperature	−40°C to +50°C

Wind Direction

Starting Threshold	0.75 mph
Delay Distance	4 ft. (50% Recovery)
Damping Ratio	0.5 to 0.6
Accuracy	
360°	±1%
540°	±1%
Range	0° to 360° or 0° to 540°
Output	
Voltage	0 to +5 VDC
Impedance	<100 ohms

Instrument Dimensions

Weight	4.3 kg & 4.8 kg (9½) & (10½ lb.)
Height	53.3 cm (21 in.)
Diameter	17.8 cm (7 in.)
Length	85 cm (33.5 in.)
Mounting	2.5 cm (1") Standard Pipe

SPECIFICATIONS

METEOROLOGY RESEARCH 1071 MECHANICAL WEATHER STATION

Wind Direction — Damped aluminum vane

Delay Distance	1.2 m (4 ft.) 50% Recovery
Damping Ratio	0.5 to 0.6
Starting Threshold	Less than 0.33 mps (0.75 mph)
Overall Accuracy	±1% full scale

Wind Run (Speed) — Fast response aluminum cups

Flow Coefficient	2.41 m (7.90 ft)/revolution
Flow per recording traverse	16 km (10 miles)
Response Distance	5.49 m (18 ft.) with 63% Recovery
Starting Threshold	Less than 0.33 mps (0.75 mph)
Overall Accuracy	±2%

Temperature — Shielded bimetal coil sensor

Low Range (Field Selectable)	−68°C to +15.5°C (−90°F to +60°F)
High Range (Field Selectable)	−35°C to +49°C (−30°F to +120°F)
Absolute Accuracy	±1.67C° (±3F°)
Resolution	0.55C° (1F°)

Humidity

Accuracy	±3%
Range	0 to 100%
Ambient Temperature	−40°C to +49°C (−40°F to +120°F)
Response	3 min., 63% of step change

Finish

White Polyurethane	A modern plastic coating that withstands extreme temperatures with superior protection and color retention.

Rainfall — Low inertia tipping bucket

Accuracy	at 5.08 cm (2") per hr within ±1%
Resolution	0.25 cm (0.01") per recording step
One Tip	7.95 cc of water
Cabling	6.1 m (20 ft) connecting cable included

Recorder — Incremental Drive

Battery-Operated	Four (4) EVEREADY Alkaline Energizer No. E95, D, 1.5 Volt batteries.
Chart Roll Speeds	Selectable 10 mm per hr runs for 65 days; or 20 mm per hr runs for 32 days
Chart Paper	Plastic coated, pressure sensitive with black trace, in 15.8 m (52') rolls. Useful chart width is 10.2 cm (4").

Weights

Model 1071, 1076	9.53 kg (21 lbs)
Shipping weight is	13.6 kg (30 lbs)
Model 1072, 1077	10.4 kg (23 lbs)
Shipping weight is	20.4 kg (45 lbs) in two containers
Field Case	add 5.89 kg (13 lbs)

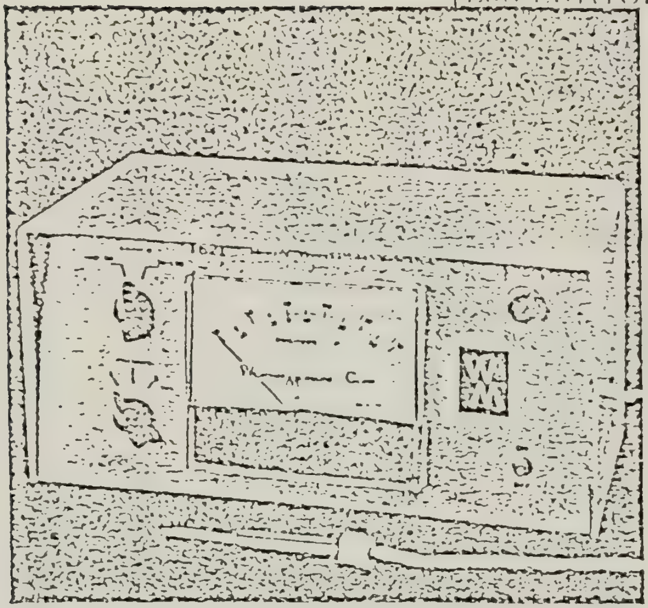
Instrument Dimensions

Weather Station	64 cm (25") height overall, body 20 cm (8") diameter, vane length 85 cm (33.5")
Rainfall Collector	61 cm (24") height and 20 cm (8") diameter

Tripods

Hot-dipped, galvanized-coated steel construction. In open position the feet form an equilateral triangle, 78.7 cm (31") on a side. The height of the instrument depends upon the length of the nominal 2.54 cm (1") dia. center pole held in place with hex set bolts at the center of the horizontal bracing.

Model 1410-8 is adjustable from 1.52 m (5') to 2.44 m (8')
Model 1412-18 is adjustable from 3.04 m (10') to 5.49 m (18')



T621 REMOTE TEMPERATURE INDICATOR
(With Recorder Output)

DESCRIPTION

The T621 Remote Temperature Indicator provides a visual indication of temperature as well as an output signal for recording of temperature on a data logger or strip chart recorder. A precision linear thermister is used as the temperature sensor. Temperature is displayed on a 4½" panel meter with an accuracy of ±1°F. The recording output signal is within ±0.3°F. The T621 has two ranges, -40°F to +60°F and 30°F to 130°F. Operation is from 115 V AC or battery power. Up to three temperature probes can be connected to the T621.

Thermister accuracy, linearity, and interchangeability is ±0.27°F over the temperature range from -22°F to 212°F. For special applications linearities as low as ±0.055°C can be provided. The thermistor is sealed with epoxy cement in a stainless steel tube or can be allowed to remain exposed to air if rapid response time is required.

The solid state electronics make use of operational amplifiers to sense changes in thermistor resistance with temperature. The resulting signal is amplified and ranged to operate the panel meter and to provide an output signal suitable for recording on either a galvanometric or potentiometric recorder or a data logger. The output signal can be adjusted to any full scale span in the range from 0 to 1 V DC or 0 to 10 ma.

Temperature sensor and temperature range selection is by means of front panel mounted switches.

For operation on battery power, a 12V DC battery is required.

For maximum reliability the probe and cable should be factory connected and sealed.

APPLICATION

Remote sensing and/or recording of soil, air, and water temperature for meteorological, hydrological, or industrial

SPECIFICATIONS

- Temperature Ranges (Std.) . . . . -40°F to +60°F and +30°F to 130°F; or -30°C to +20°C and °C (Custom boards; any 100°F range between -2? and 212°F.)
- Accuracy
  - Panel Meter . . . . ±1°F
  - Recorder Signal Output . . . . ±0.3°F
- Temperature Sensor . . . . Linear thermister, ±0.15°C linearity, std; ±0.055°C optional.
- Sensor Housing . . . . Stainless steel sheath or exposed bead
- Power . . . . 115 V AC, 50/60 Hz or +12 DC; 10 m
- Size . . . . 12"W x 6½"H x 6½"
- Output to Recorder . . . . . . 0-1V DC or 0-10 mA standard, others on request
- Weight/Shipping (less cable) . . . . 4 lbs/10 lbs

ORDERING SPECIFICATIONS

• T621	Remote Temperature Indicator, complete with one standard temperature probe in stainless steel tube (specify sealed or exposed bead.) With recorder output signal 115 VAC, 50/60 Hz. Specify °F or °C.
• T621-DC	Remote Temperature Indicator, s as above except operates on 12V DC or 115 VAC, 50/60 Hz.
• T621-BD105-1	Ambient Temperature Circuit Board fo custom systems, including calibration r sistors for 0 and full scale calibratio points, mating 22 pin connector, premiu range resistors.
• T621-T18	Air Temperature Standard Thermist Probe, ¼" o.d. x 3" L stainless ste jacket, interchangeability ±0.15°C, les cable.
• T621-T018	Same as above except with perforate stainless steel jacket.
• T621-TP18X	Air Temperature Premium Thermisto Probe, ¼" o.d. x 3" L, stainless ste jacket, interchangeability ±0.055°C.
• T621-TP018X	Same as above except with perforat stainless steel jacket.
• T621-TW18	Water Temperature, standard thermisto probe, ½" o.d. x 3" L, stainless ste jacket, interchangeability ±0.15°C.
• T621-TWP18X	Water Temperature, premium thermisto probe, ½" o.d. x 3" L, stainless ste jacket, interchangeability ±0.055°C.
• T621-C	3 conductor cable to connect air tem perature probe to indicating console
• T621-CW	3 conductor neoprene jacketed cable t connect water temperature probe to in dicating console.

SPECIFICATIONS

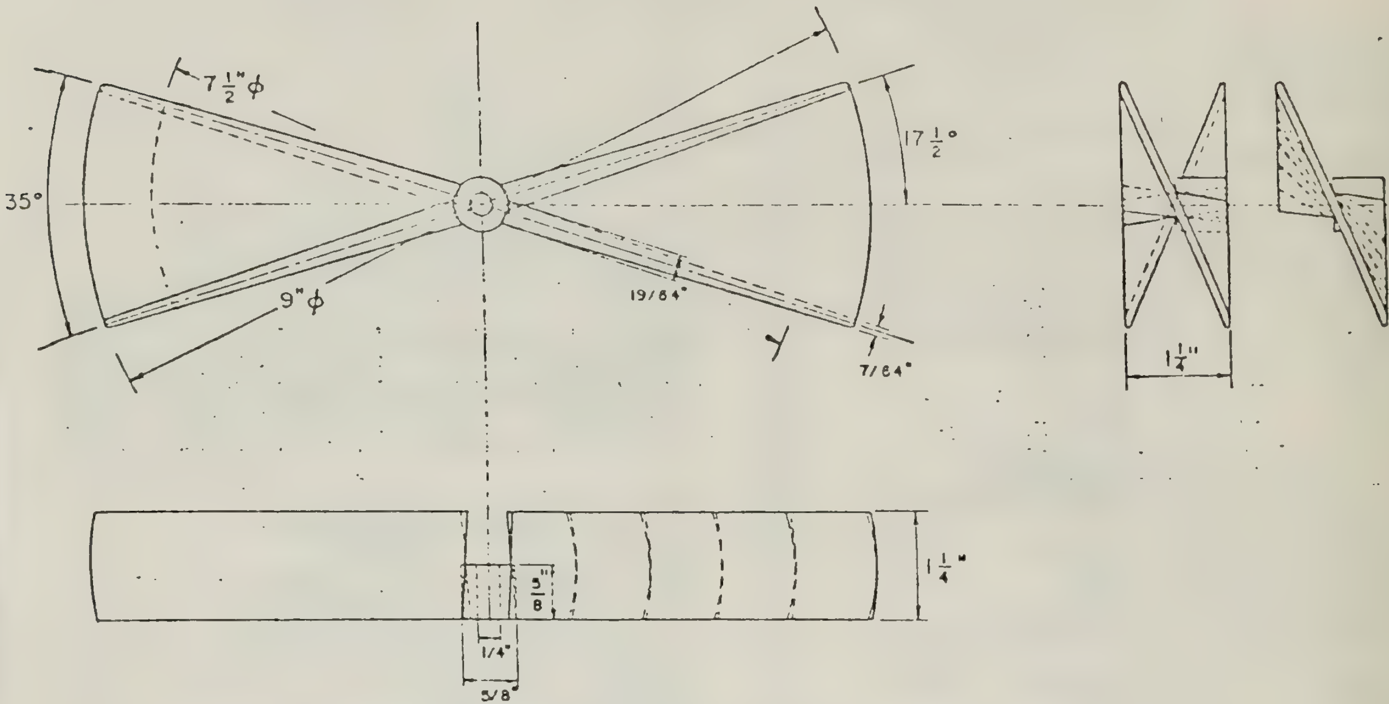
METEOROLOGY RESEARCH 840 TEMPERATURE SENSORS

Temperature & Relative Humidity Sensor/840-1, 2, 3, 7, & 842-1, 2, 3

Sensor Housing: (Model 840, 842 Aspirator)		
Effect of Radiation	<0.05°C under maximum solar radiation conditions	
Air Flow	5 ft/sec for RH — 15 ft/sec for Temp	
Blower	Continuous duty	
Air Flow Indicator	Micro switch (optional)	
Sensing Elemeot:		
Temperature Sensing Elements:	P/N ES 15966 Probe	P/N ES 16196 Probe
Accuracy	± 0.15° C	± 0.10° C
Output	15968 Ω to 5835.5 Ω	20158 Ω to 7242 Ω
Range	-30° C to + 50° C	-50° C to + 50° C
Humidity Sensing Element:	P/N ES 17350 Transducer	
Accuracy	±3.0% R.H.	
Range	0% to 100% Relative Humidity	
Physical Characteristics		
Overall Length	Model 840	Model 842
	106.4 cm (41.9in)	119.4 cm (47 in)
Glass Shields	5.6 cm (2.18 in) OD x 3.2 cm (1.25 in) ID x 19.0 cm (3.5 in) long	
Mounting	Model 544 Mounting Bracket	
Blower Housing	16.5 cm (6.5 in) diameter	
Shipping Weights	Model 840	Model 842
	5.9 kg (13 lb)	6.8 kg (15 lb)
Power Requirements		
Blower	115 V/50-60 Hz 7 watts nominal	
Environmental Capabilities, Operational		
Temperature	—50°C to +50°C	
Humidity	0% to 100% RH including precipitation	
Wind Speeds	To 100 mph	
Altitude	To 20,000 feet	
Sand and Dust	As normally encountered in desert areas	
Salt Atmosphere	As normally encountered in coastal areas	

PROPELLER SPECIFICATIONS

MAXIMUM RESPONSE POLYSTYRENE PROPELLERS



CATALOG NO: PRICE:	21180/27105 $24.00	21182/27106 $17.00	21183/27107 $19.00	21184/2710[illegible] $26.00
BLADES:	4	2	2	4
DIAMETER:	9 IN.	9 IN.	7½ IN.	7½ IN.
RANGE (HEAD-ON):	70 MPH	90 MPH	100 MPH	90 MPH
RANGE (ALL ANGLES):	50 MPH	75 MPH	90 MPH	70 MPH
THRESHOLD:	0.2-0.4 MPH	0.3-0.5 MPH	0.4-0.6 MPH	0.3-0.5 MPH
DISTANCE CONSTANT:	3.1 FT.	2.4 FT.	2.8 FT.	2.7 FT.

These propellers are molded of expanded polystyrene beads. The helicoid form has a pitch of 360° in 1.04 ft (or 0.96 rev per ft). Four blade propellers are made from two blade moldings dovetailed together at the hub. Epoxy fillets are added to the hub area for increased strength and propellers are then sprayed and balanced with special formulation acryli paint. Propellers 7½" in dia. are fabricated from 9" dia. moldings with slightly larger epoxy fillets added in the hub area.

our blade propellers provide slightly better symmetry of response to various wind angles especially near the stall region (90° wind angle).

Threshold is measured with propeller mounted on 3/16" dia. shaft supported on precision instrument grade ball bearings with light chopper type transducer. Miniature tachometer generator increases threshold 0.1-0.[illegible] MPH for 9" dia. and 0.2-0.3 MPH for 7½" dia. propellers.

Model 300A Specifications

Transmitter:	Frequency – 1600 Hz Pulse Width – 50, 100, 200 ms Output Power – 25 Watts standard 100 Watts optional Output Impedance – 8 Ohms Pulse Repetition Rate – 1 per 9 sec. (500 m scale) – 1 per 18 sec. (1000 m scale)
Receiver:	Gain – 10^8 Gain Compensation – proportional to time of echo return. Bandwidth – 20, 40, 80 Hz Range – 500 m, 1000 m full scale – 20 m minimum Resolution – 20 m
THI Display:	Writing Technique – electrical engraving of conductive paper. Chart Size – 6" (15.2 cm) wide by 72' (22 m) long Chart Speed – 1.2" (3.05 cm) per hour Chart Duration – 28 days
Size and Weight:	17" W x 17" H x 6" D, 45 lbs.
Power Input:	115V, 60 Hz, 50W average, 250W peak

Model 300A Options

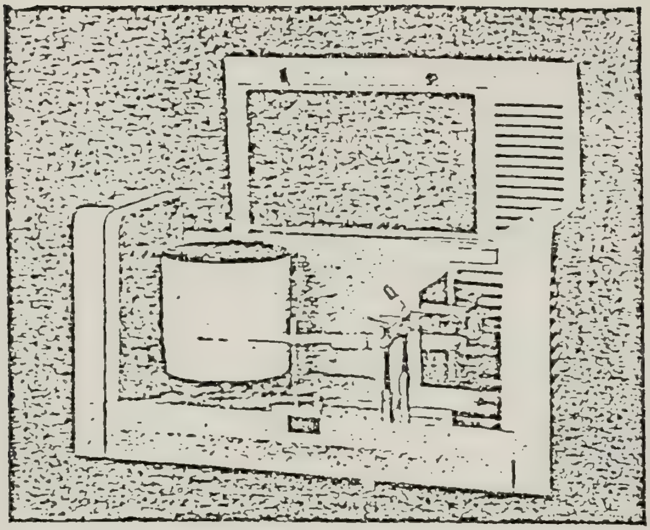
Option 001 – 100W Transmit Power - improves signal-to-noise by 6 db.

Option 002 – Allows use of 220-240V power

Option 003 – Allows use of 50 Hz power

Option 004 – Full-scale range of 250 m or 500 m

Option 005 – Full-scale range of 750 m or 1500 m



H324 *SKYLINE* HYGROGRAPH

DESCRIPTION

Features the new WeatherMeasure *Skyline* series instrument case design. Advantages include wrap around front window for easy record observation, modern styling, ready access to all moving parts through the hinged door which lifts up and back, and the use of corrosion resistant materials such as corrosion resistant duraluminum alloy, brass and stainless steel for all parts.

Humidity is measured over the range of 0- 100% using time-tested human hair as the sensing element. Expansion and contraction of the dual hair bundles are magnified by a unique lever system. One hair bundle moves a lever fulcrumed at the center and connected to a second hair bundle. The second bundle of hair is looped through a lever which moves the pen arm. Non-linearity in the expansion and contraction of the hair due to changes in humidity are corrected by use of two opposed quadrants in the linkage system.

Calibration adjustments are easily accomplished by rotating the hex nut controlling the tension on the hair bundles. The key used to wind the clock is also used for calibration adjustments. Openings in the sides and base of the instrument permit free movement of ambient air to the hair bundles.

An 8 day spring wound clock is mounted on the sturdy cast aluminum instrument base. Change gears are provided to rotate the clock drum at 1-day or 7-day intervals. The drum revolves in 26 hours when the 1-day gear is used, and in 172 hours when the 7-day gear is used. Thus, the recording chart can be changed each day or each week before the pens have reached the chart clip.

All internal moving parts are chrome-plated brass or stainless steel. Corrosion resistant parts are used throughout. Case sides are indented at the top to serve as hand grips for moving. An ink bottle well is provided on the base of the instrument. An external pen lifter which can be operated from outside the case prevents inadvertent pen movement when the case is opened. A storage tab is provided for the calibration and clock winding key.

APPLICATION

Can be used indoors, or outdoors when installed in an instrument shelter. Provides a 1-day or 7-day trace of relative humidity. The attractive styling and modern design will enhance an instrument display.

SPECIFICATION

- Range .... 0-100% R.H.
- Sensor .... Two human hair bundles
- Accuracy .... ± 1% between 20 and 80%; approximately 3% at extremes
- Sensitivity .... Less than 1%
- Chart Scale Divisions 1%
- Chart Size .... 11½"l x 3½"h
- Chart Drive .... 8-day spring wound
- Drum Rotation .... 1-day and 7-day (26 hr. & 172 hr) by change gear provided
- Weight/Shipping .... 9 lbs/14 lbs

ORDERING SPECIFICATION

- H324 — *Skyline* Hygrograph complete with pen, ink and 100 charts.
- H324-HB — Replacement hair bundle, set of 2.

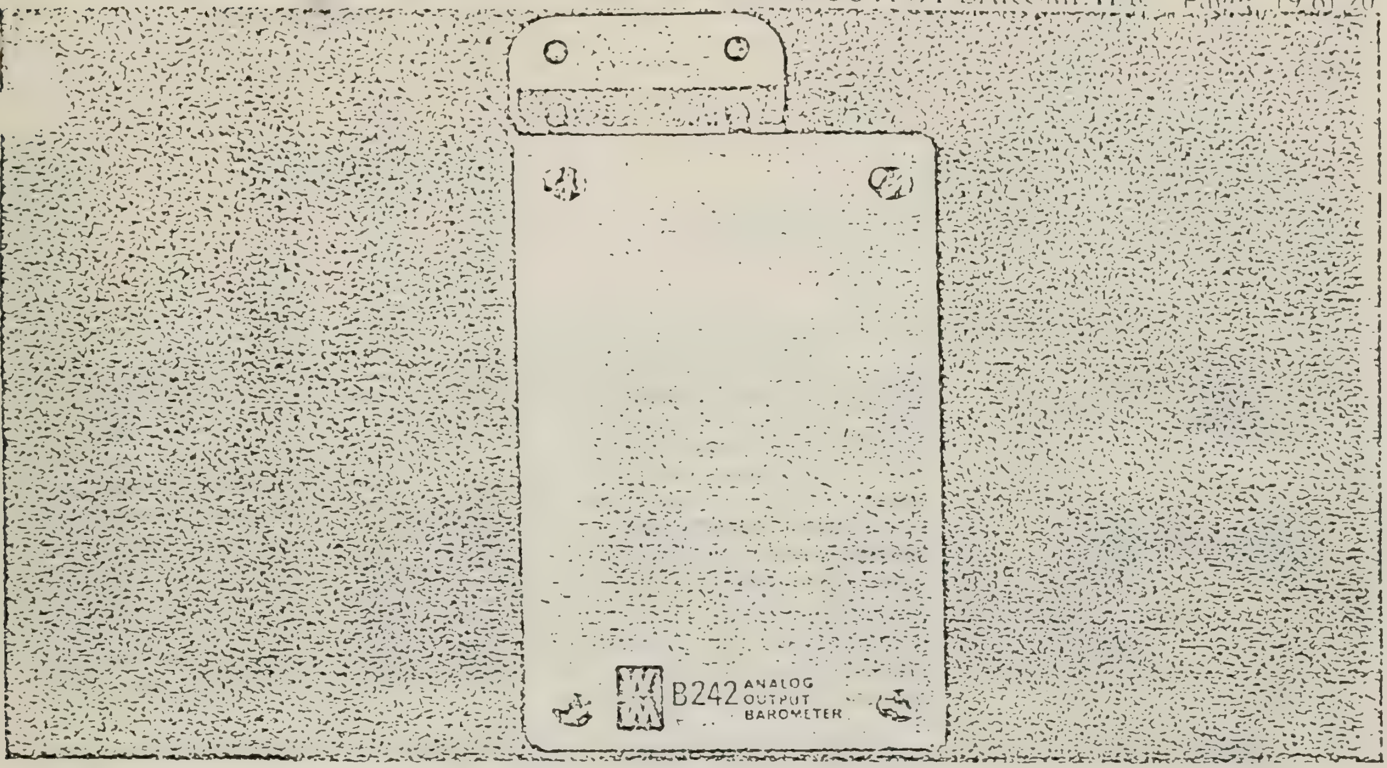
CHARTS

- C324-W 0 to 100% – 7-day drum rotation.
- C324-D 0 to 100% – 1-day drum rotation.

All Prices F.O.B. Sacramento

THIS INSTRUMENT IS AVAILABLE FOR LEASE — prices available on request.

SPECIFICATIONS
WEATHERMEASURE B242 ANALOG OUTPUT BAROMETER



DESCRIPTION

he Model B242 Analog Output Barometer provides an out-·· voltage that is linearly proportional to pressure. The analog ·t can be used for recording barometric pressure on digital data loggers, strip chart recorders, and for telemetry links, or other systems requiring an analog input signal of pressure.

The Model B242 contains a multicell aneroid sensor which positions the core of a linear variable differential transformer (LVDT). The output voltage of the LVDT, which is linear with core position (hence with pressure), is amplified to the level desired. All mechanical and electrical components are designed to achieve linearity and a low temperature coefficient. The aneroid cells are of NiSPAN-C and have a thermal expansion coefficient of essentially zero.

The gain and zero point of the amplifier may be adjusted to produce an output varying from 0 to 1 VDC over any 100 mb interval between 600 and 1065 mb. The gain is normally set at the factory and the zero point set in the field to correspond to the elevation of the installation.

The sensor housing is airtight and provided with a pressure fitting so that atmospheric pressure at remote locations or any other pressure in the range of 600 to 1065 mb (17.7 to 31.45" Hg) may be measured.

It is also available with other output voltages or for lower pressure levels as options.

APPLICATION

The principal use of the Model B242 Analog Output Baro-··er is as the barometric pressure sensor for data loggers, strip ·rt recorders, telemetry and remote indicator systems. It is ·able for use at elevations to 12,000 ft.

SPECIFICATIONS

- Range .... Any 100 mb interval from 600 to 1065 mb (standard)
- Output .... 0-1 VDC (standard)
- Resolution .... Infinite
- Linearity .... ± 0.5 mb, over 100 mb intervals (0-40°C) ± 1.0 mb, over 100 mb interval (−20°C to +40°C)
- Ambient Temperature .... −20 to 40°C
- Power .... 115V, 50/60 Hz, or 12 VDC
- Size, Sensor Housing .... 9"h x 5½"w x 5½"d
- Size, Electronics Housing .... 6"h x 11¼"w x 6½"d
- Weight, Total .... 9 lbs.
- Shipping Weight .... 18 lbs.

ORDERING SPECIFICATIONS

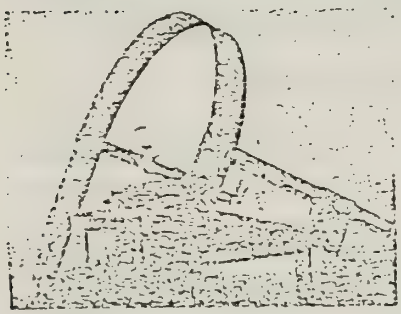
- B242 — Analog Output Barometer, including sensor in housing, power supply and signal conditioning electronics in separate cabinet.
- B242-S — Analog Output Barometer, less power supply and signal conditioning.
- BD242-116 — Power Supply and signal conditioning circuit card.
- B242-C — Cable, 4 conductor, to connect sensor to electronics. All Prices F.O.B. Sacramento

All Prices F.O.B. Sacramento

WEATHERMEASURE CORPORATION
A Subsidiary of Systron-Donner Corp.
P.O. BOX 41257 • SACRAMENTO, CALIFORNIA 95841
TELEPHONE (916) 481-7565

990.00

No. 646



No. 646C(1)

No. 646C(2)

EPPLEY PRECISION SPECTRAL PYRANOMETER. Designed for the measurement of sun and sky, totally or in defined wavelength bands, this instrument is an improved and smaller model of a device introduced in 1957. The sensing element, designed to withstand mechanical vibration and shock, is a wire-wound thermopile, mounted in a chromed brass case. Parsons' black lacquer, non-selective to different wavelengths, covers the receiver surface and overall are a pair of concentric hemispheres of Schott glass, removable and replaceable. The inner glass is clear WG7, transparent to wavelengths approx. 285/2,800nm. For the outer glass there is a choice: WG7, as above, or any of the following, with the centers of lower sharp cutoff approximately as noted: yellow GG14, 500nm; orange OG1, 530nm; red RG2, 630nm; dark red RG8, 700nm.

A white enameled guard disc fits above a cast bronze stand with adjustable leveling screws and a bubble type level—a desiccator that can be inspected is also supplied. Instrument characteristics include Sensitivity, 5mV per cal./cm²min.; Impedance, 300 ohms; Temperature Compensation, ±1% from −20/+40°C.; Response, linear up to intensities of 4 cal./cm²min.; Response Time, for 66% change, 1 sec.; Mechanical Vibration, up to 20 g's.

Calibration reference is Eppley primary standard group of Angstrom pyrheliometers reproducing International Pyrheliometric Scale. Wt. 5/ shpg. 13 lbs.

Accessories:

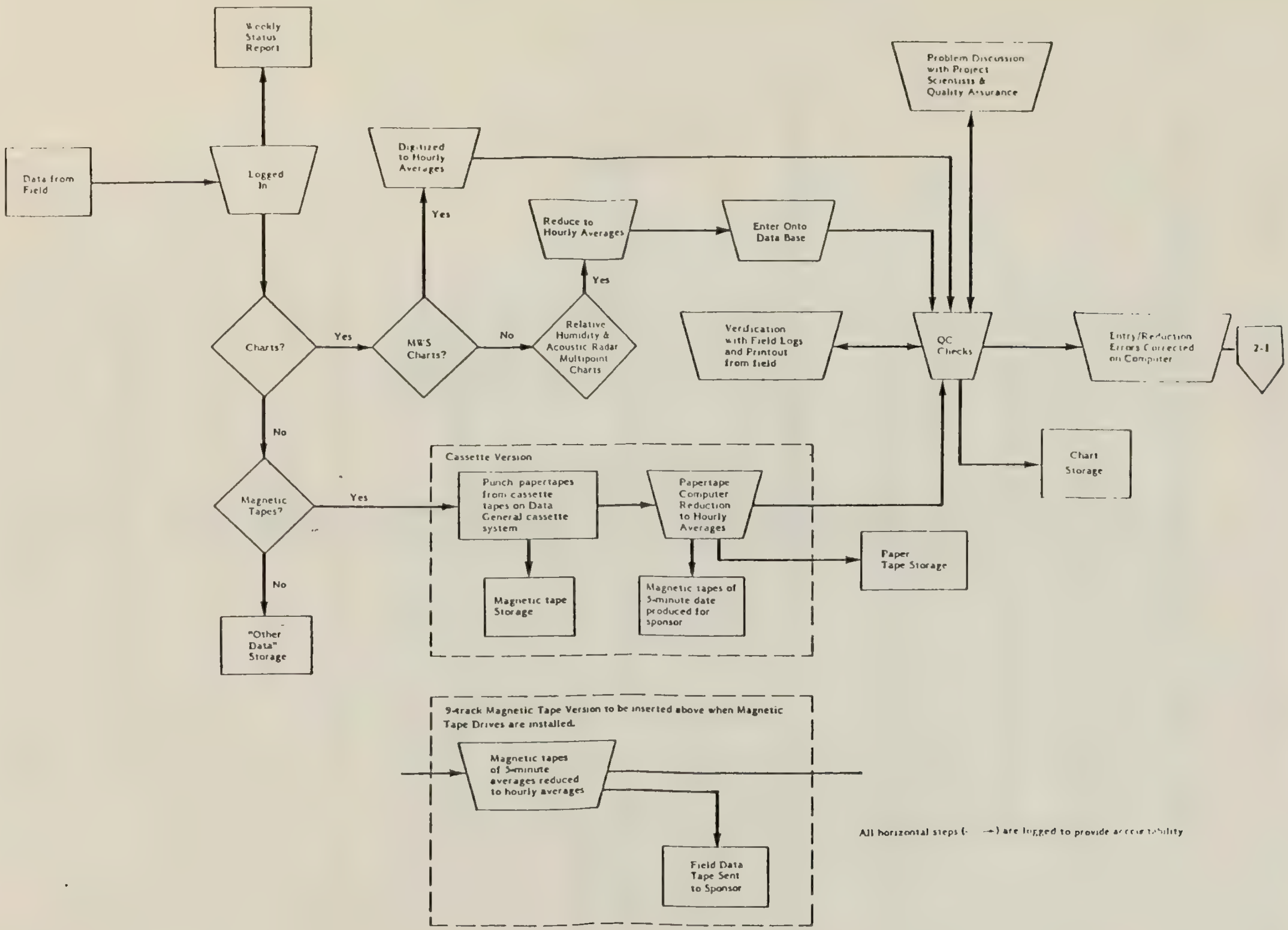
A. Outer glass Schott filters, specify WG7, GG14, OG1, RG2, or RG8. Includes mount.
B. Potentiometric recorders, see Nos. 613-1, 644
C. Shadow bands with correction data for use with No. 646 or 645-48, (1) for latitude 0/60° N or S (2) for latitude 60/95° N or S.

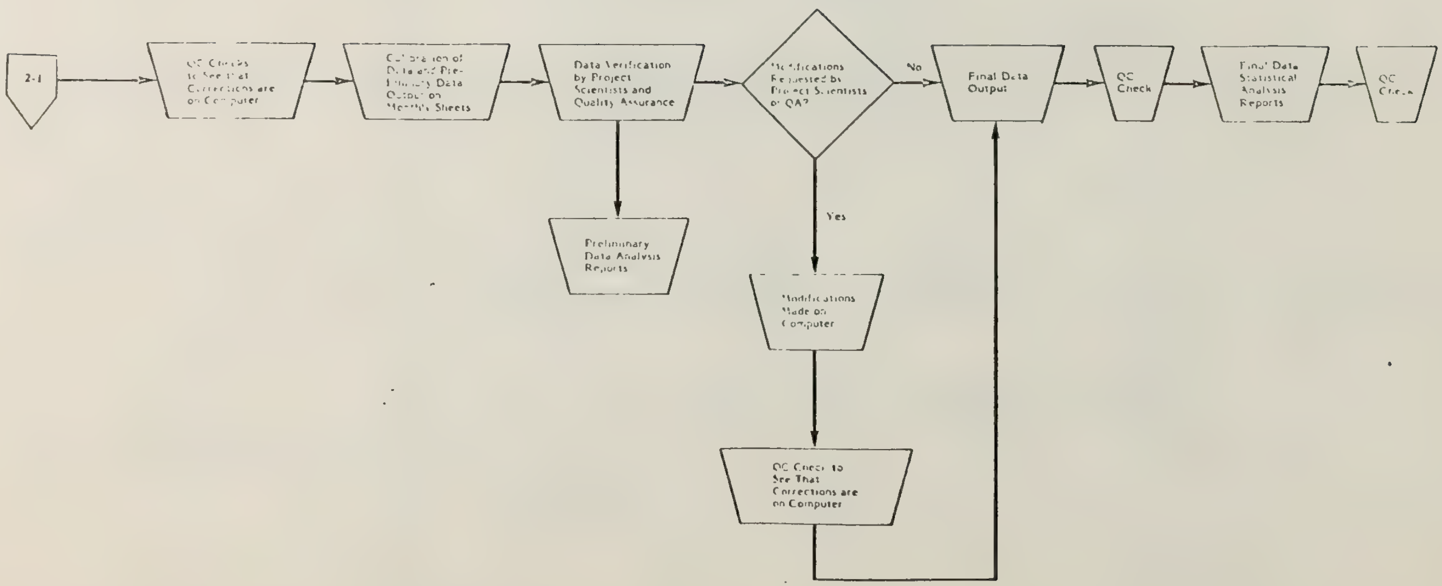
APPENDIX B

Excerpt from AeroVironment's

Data Reduction Manual

176.9 Cb Oil Shale Project Data Processing Flow Diagram.




2-1
Data Verification by Project Scientists and Quality Assurance
Preliminary Data Analysis Reports
No
Yes
Final Data Output
QC Check
Statistical Analysis Reports
QC Check to See That Corrections are on Computer

176.10 Standard Data Procedures for Cb Shale Oil Project

The following is the standard monthly flow of data arriving from Cb:

(Cassette Data Reduction) (September 1977-January 1978)

1. The data arrives from the field and is logged in by a data clerk.

2. Cassette tapes are sent to Computer Operations.

3. Computer Operations converts the cassettes to paper tapes on the in-house Data General cassette computer system.

4. The paper tapes are loaded onto the AQDMS data base and 5-minute averages are automatically stored on a 9-track magnetic tape. Hourly averages are stored on the data base.

5. Printouts of the data hourly averages are made which are spot checked against the 30 minute averages on the Texas Instruments Silent 700 printout which arrives from the field.

6. The station logs are scanned by a data technician to look for power outages, instrument malfunctions, and the like.

7. Corrections determined in steps 5 and 6 above have been made to the hourly averaged data.

8. Quality Assurance personnel verify the data.

9. Monthly calibrations are applied to the data.

10. Quality Assurance personnel verify the data.

11. Monthly reports are produced from the data, along with a data tape of hourly averages.

(9-Track Magnetic Tape Reduction) (Scheduled to start in May 1978)

When the 9-track drives are installed these changes will be made to the above:

2. Magnetic tapes are sent to Computer Operations.

3. eliminated

4. The magnetic tapes are converted into hourly averages as they are loaded onto the AQDMS data base. The field tape is sent to the sponsor.

(Multipoint Reduction) (started in January 1978)

When the multipoints are installed and the cassette system is not recording data, these changes will be made to the above procedure:

2. eliminated

3. The multipointed are reduced to hourly averages by hand and entered onto paper tape.

4. The paper tapes are loaded onto the AQDMS data base and stored as hourly averages.

5. Printouts of the data hourly averages are made.

176.11 Specific Techniques

These are specific techniques which are used to produce various reports:

176.11.1 Wind Direction Averages

Wind direction is averaged by the computer by using standard vector addition except that wind speed is assumed to be one (unit vector addition). The wind direction hourly averages are computed from five-minute averages (as are the other components).

176.11.2 Missing Data Codes

Missing data is replaced with a letter code describing why the data is missing. The letter codes are:

- CA Calibration (calibration, system check)
- MT Maintenance (changing paper, tape, charcoal)
- FO Flame out (on the GC-THC,HC, CH_4, CO, SO_2, H_2S, Total Sulfur)
- IM Instrument malfunction (instrument failures)
- PF Power failure (generator failure)
- RF Recording sytem failure (chart jams, runs out)
- LI Local interference (car nearby)
- OE Operator error (field tech leaves switch in wrong position, out of AV's control)
- OS Off scale (at top of chart)
- IN Interference (CO_2 interference on sulfur data, SO_2 interference in oxidant readings).
- SE Special experiment (instrument removed for tracer study, etc.)
- OR Out for repair (instrument removed from site with no replacement)
- VA Variable wind direction
- CM Calm (no wind direction when wind speed = 0).
- UN Unlimited ceiling (reported to NWS Stations)
- Blank (causes a blank to be printed as in the beginning of a new month before a component starts).

176.12 Report Listing

The following is a listing of the monthly data reports' contents (from the AV Statement of Work). Some of the reports are combined on a single page.

MONTHLY REPORT CONTENTS

A: Air Quality and Meteorological Data

1. Hourly tables by parameter by site

2. Downtime hours by parameter by site

3. Monthly % efficiency by parameter by site

4. Hourly tables of stability class determined by ΔT

5. Five maximum independent sliding averages (1, 3, 8, 24 hours, as appropriate) with corresponding WS/WD for those parameters with a NAAQS air quality standard (O_3 - 1 hour/ CO - 1 hour and 8-hour; SO_2 - 3-hour, 24-hour; particulates - 24-hour; Hc (CH_4 reduced) - 3 hours (6-9 a.m.)).

6. Monthly and daily averages

7. Descriptive regional meteorological summary

B: Acoustic radar hourly mixing height, inversion height, and stability type.

C: System description – initial report and again after major changes

D: Data acceptance algorithm

E: Pibal data utilizing a double theodolite presenting wind speed, wind direction, and temperature versus altitude.

1.2.4 Data Problem Reporting

Whenever a problem is noticed in any data, or should data be missing, then a "Data Processing Problem Report" is used. It notifies the Project Manager that there is a problem, tells him what action DP is taking (even if there is no action) and finally allows him to decide the best manner to handle the problem.

A Problem Report and the "Data Problem Reporting Flow" are attached as a reference.

Project________ Site_______ Component(s)________________

Period of Time Affected:________________________________

Problem:____

DP Action Being Taken:__________________________________

By:_____________________ DP Release:____________________

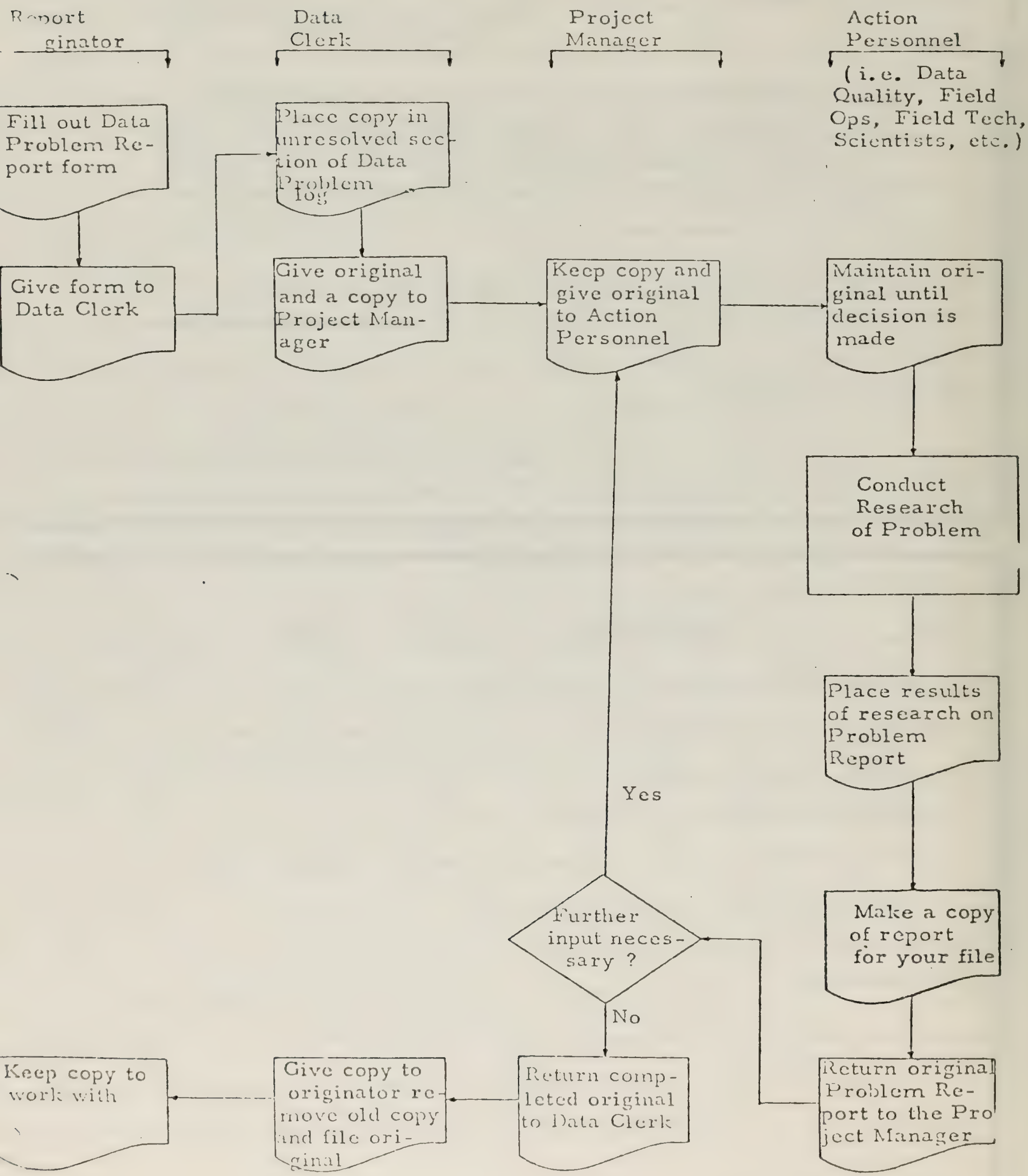
Assigned to:____________________

List:	Actions Taken	Dates	Initials

DP Instructions:____

Project Manager Okay:__________________ Date_____________

Data Problem Reporting Flow



APPENDIX C

AeroVironment's Calibration Records

Parameter	Pages
NO/NO_x	3
SO_2	3
O_3	2
$THC/CH_4/CO$	3

NO/NO_x

CALIBRATION RECORD

Date ____________________ Location/Site No. ____________________

Trailer S/N ____________ Time __________ Hrs. - __________ Hrs.

Chemiluminescent NO/NO_x Analyzer

Make ______________________________ Model ____________

S/N ______________________________

Indicated Flow:

NO_x sample ____________________ cc/min

NO sample ____________________ cc/min

O_3 ____________________ cc/min

Vacuum ____________________ in Hg

Settings:	NO_x (at start)	NO (at start)	NO_2 (at start)	NO_x (at completion)	NO (at completion)	NO_2 (at completion)
Zero	____	____	____	____	____	____
Span	____	____	____	____	____	____

Test readout:	NO_x (at start)	NO (at start)	NO_2 (at start)	NO_x (at completion)	NO (at completion)	NO_2 (at completion)
Electrical %	____	____	____	____	____	____
Optical ppm	____	____	____	____	____	____

Converter Efficiency: __________ %

Calibration Method: Zero: ______________________________

Span: ______________________________

Calibration Equipment Serial Number ______________________________

Calibration Gas:

Cylinder Number ______________ Analysis Date: ______________

Analysis: ____________________

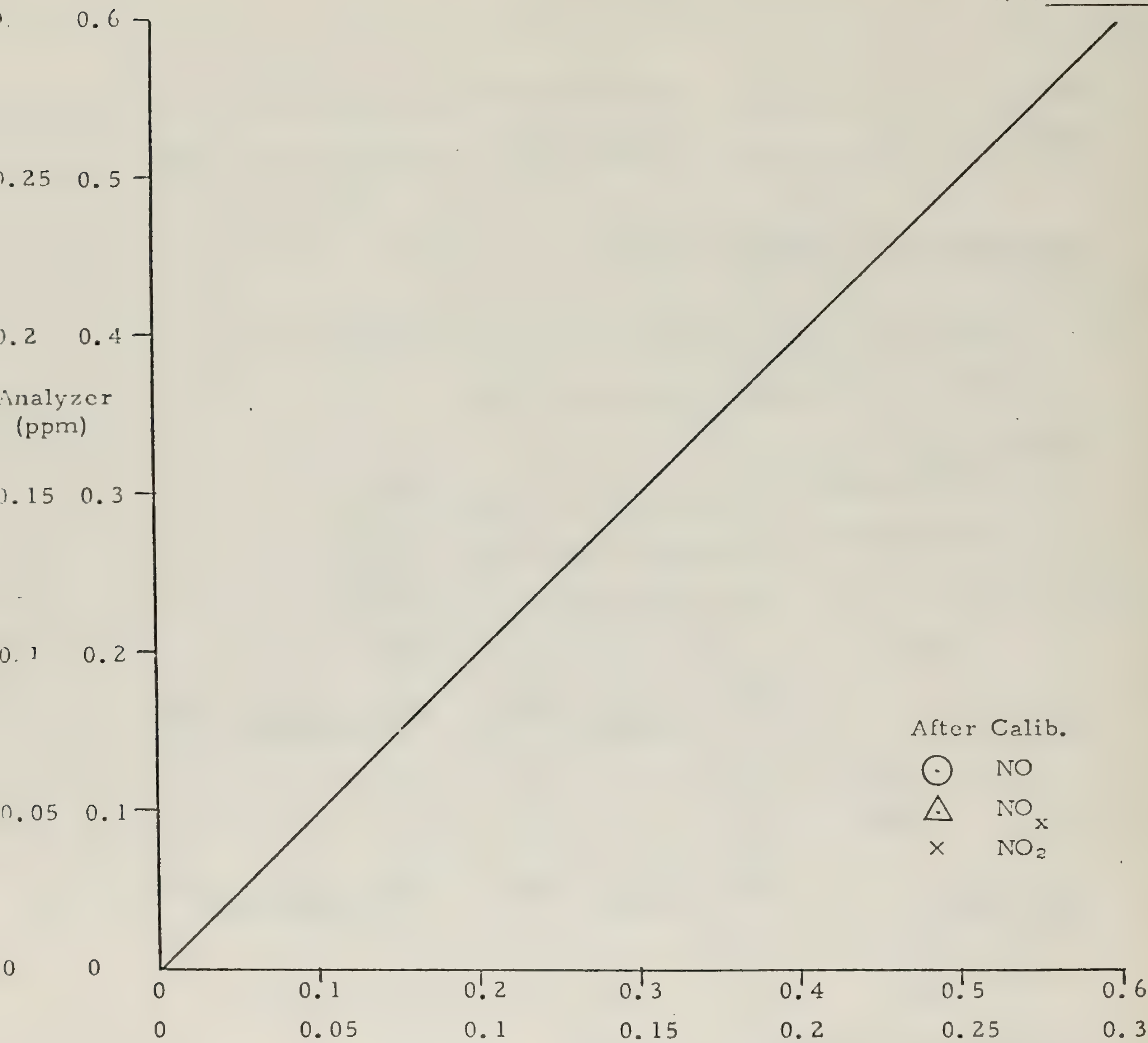
Calibrated by: ______________________

Comments: ____

Date _______________ Location _______________ Trailer S/N _______ Site No. ___

Chemiluminescent NO/NO_x Analyzer Make _______________ Model _______________

S/N _______________



REFERENCE BASE (give 0 and minimum 2 points)

Flow Setting	Press. psig	NO in ppm	NO_2 in ppm	NO read ppm	NO_x read ppm	NO_2 read ppm	Remarks

AV-F-FO20

SO_2

CALIBRATION RECORD

Date ______________________ Location/Site No. ____________

Shelter S/N ____________________ Time ________ Hrs. - ________ Hrs.

Sulfur Dioxide Analyzer

Make ______________________ Model ______________________

S/N ______________________

		BEFORE		AFTER
Flow settings	air	________		________
	H_2	________		________
Zero setting		________		________
Span setting		________		________
High Voltage Supply		________	V	________
Oven Temperature		________	°C	________
Burner Block Temperature		________	°C	________
Exhaust Temperature		________	°C	________

H_2S Scrubber Efficiency: ________ %

Calibrator: ______________________ S/N ______________________

Calibration Method: Zero ____________

SO_2 Perm. Tube No. ____________

H_2S Perm. Tube No. ____________

Temperature ________ ± ________ °C

Calibrated by: ______________________

Comments: ____

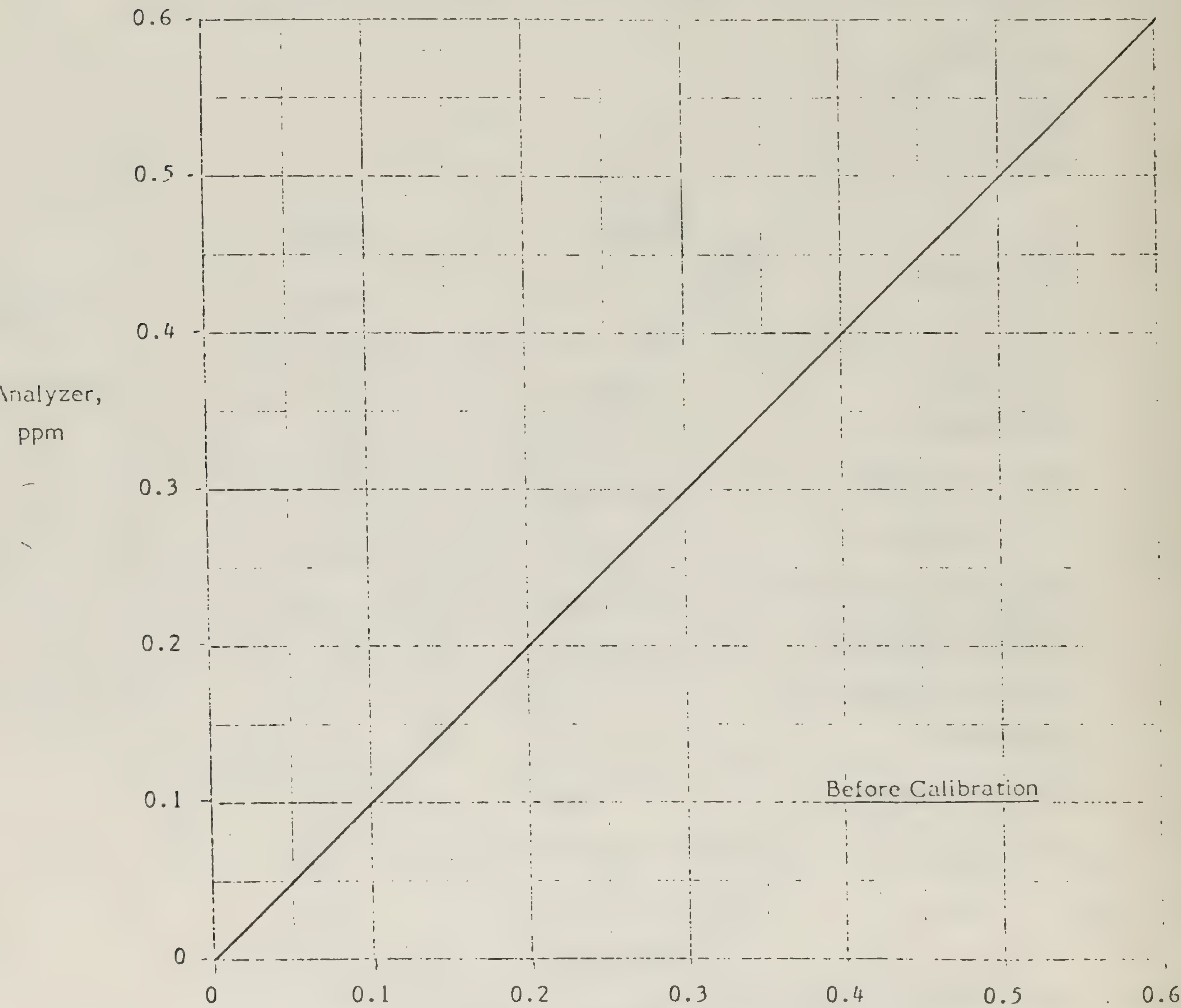
____

____

SO_2
CALIBRATION CHART

Date ________ Location ____________ Shelter S/N ____________ Site No. ________

Sulfur Dioxide Analyzer Make ______________ Model ________ S/N ____________



REFERENCE BASE (Give 0 and 5 span points)

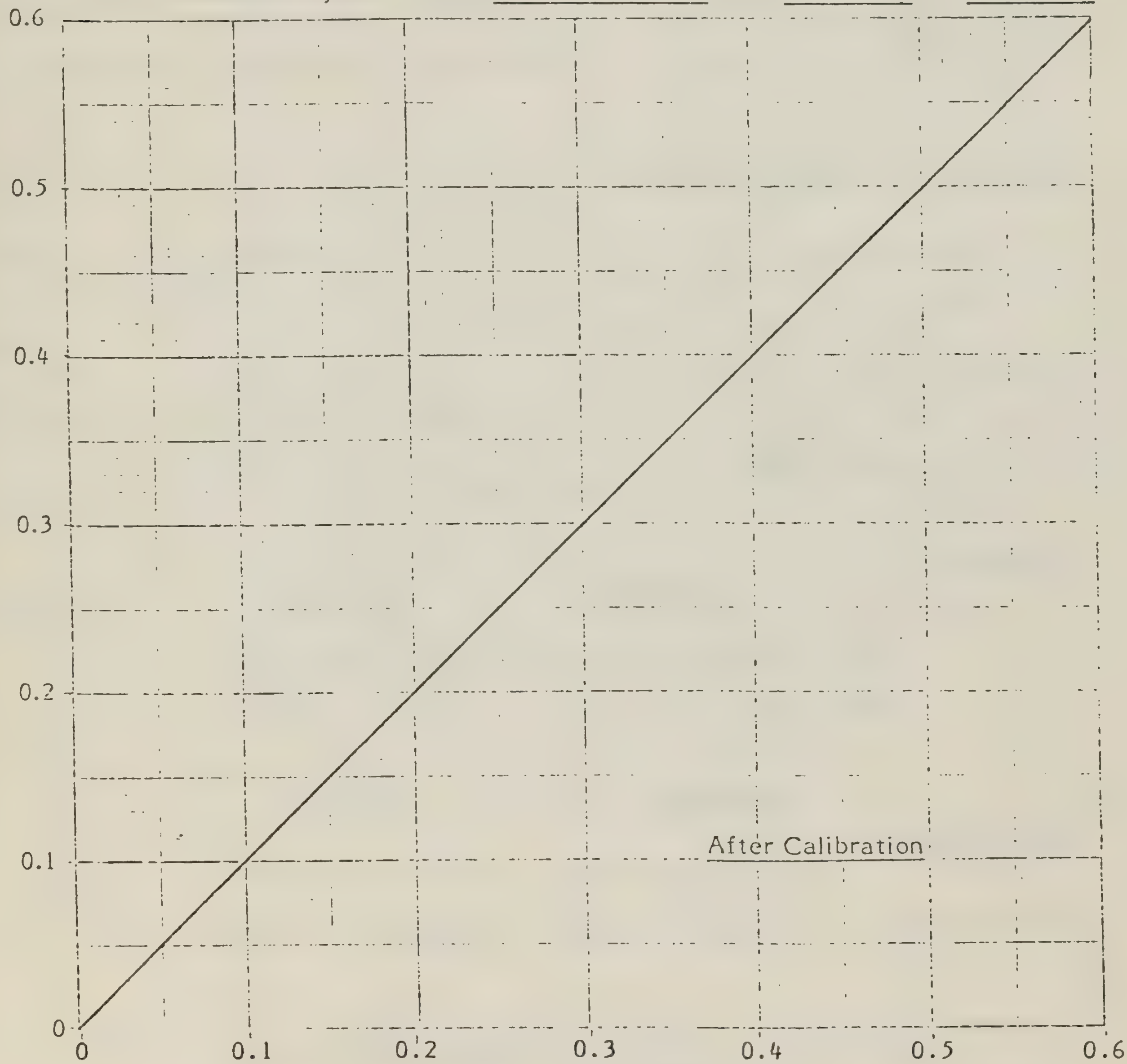
Flow Setting	SO_2 in ppm	H_2S in ppm	SO_2 read, ppm	Remarks

SO_2

CALIBRATION CHART

Date ________ Location __________ Shelter S/N __________ Site No. ______

Sulfur Dioxide Analyzer Make ______________ Model _________ S/N __________



REFERENCE BASE (Give 0 and 5 span points)

Flow Setting	SO_2 in ppm	H_2S in ppm	SO_2 read, ppm	Remarks

O_3

CALIBRATION RECORD

Date ____________ Location/Site No. ____________

Trailer S/N ____________ Time ________ Hrs. ________ Hrs.

Chemiluminescent O_3 Analyzer

Make ____________ Model ____________

S/N ____________

Indicated Flows:

C_2H_4 ________ cc/min at inlet pressure ________ psig

Sample + C_2H_4 ________ cc/min

Settings:

	BEFORE	AFTER
Zero		
Span		

Test:

	BEFORE	AFTER
Electrical %		
Optical ppm		

Calibration Method: Zero ____________

Span ____________

Calibration Equipment Serial Number ____________

Calibrated by: ____________

Comments: ____________

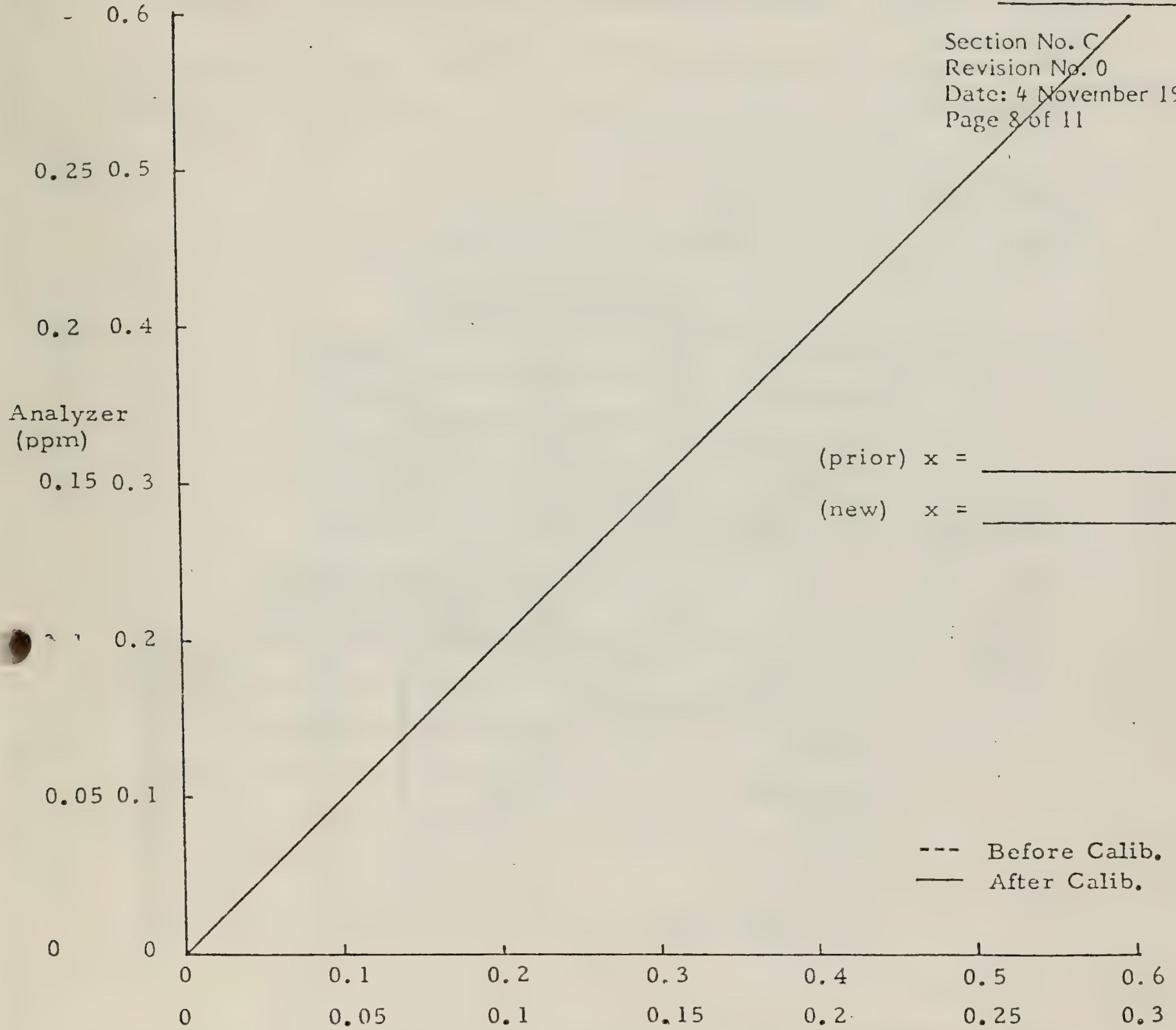
____

CALIBRATION CHART

Date ______________ Location ____________ Trailer S/N ____________ Site No. ______

Chemiluminescent O_3 Analyzer Make ____________ Model ____________

S/N ______________



REFERENCE BASE (give 0 and minimum 2 points)

	Flow Setting	Position	O_3 in ppm	O_3 read ppm	Remarks
Initial					
Final					

THC/CH_4/CO

CALIBRATION RECORD

Date ____________________ Location/Site No. ____________________

Trailer S/N ____________________ Time ________ Hrs. - ________ Hrs.

HC/CO Gas Chromatograph:

Make ____________ Model ____________ S/N ____________

Pressures:

	BEFORE	AFTER	
H2 fuel			psig
Burner air			psig
Air carrier			psig
Service Air			psig
H_2 carrier			psig

Timing:

	BEFORE		AFTER		
	On	Off	On	Off	
Valve B					Sec
Component 1 (THC)					"
Valve A					"
Auto Zero A					"
Component 2 (CH_4)					"
Auto Zero B					"
Component 3 (CO)					"

Calibration Gas:

Cylinder Number ____________________ Analysis Date: ____________

Analysis: THC ____________, CH_4 ____________, CC ____________

Calibrated by: ____________________

Comments: ____

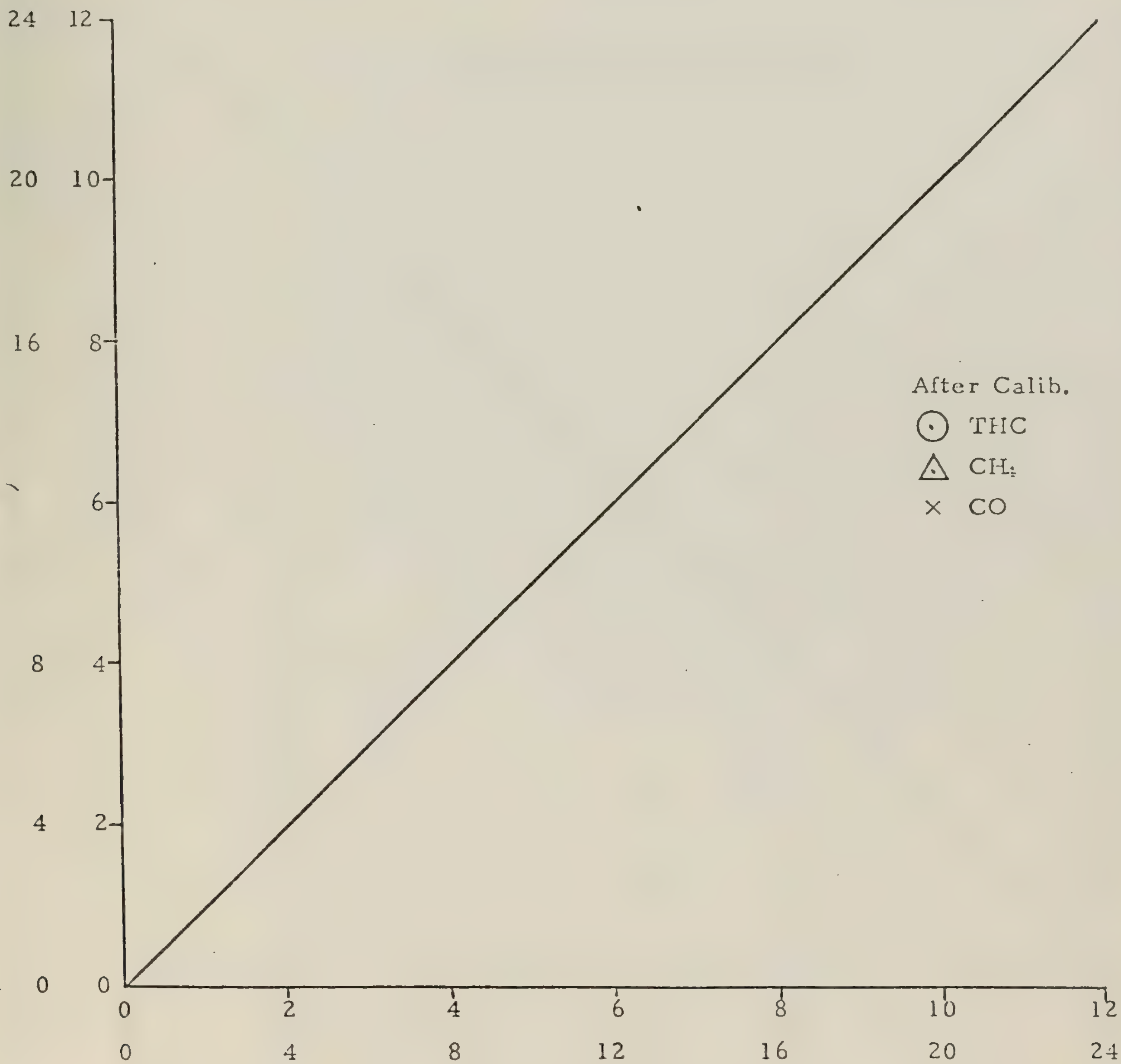
Attach manual and automatic chromatograms.

CALIBRATION CHART

Date ________________ Location ___________ Trailer S/N __________ Site __________

HC/CO Gas Chromatograph   Make _______________ Model ___________

S/N _____________



Calibration Gas (ppm)

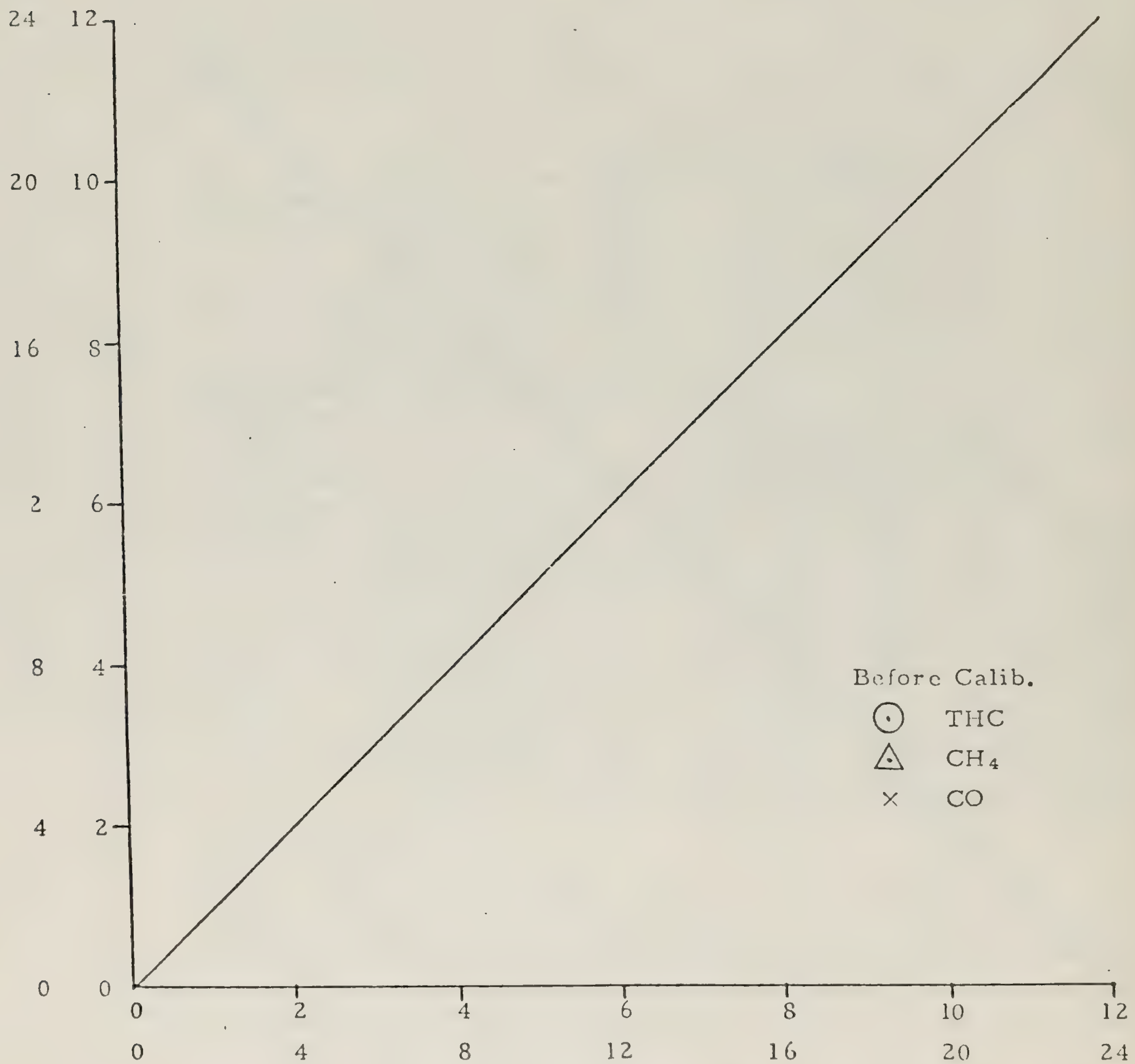
Calib. Base	Span	Zero	Remarks
THC ppm			
CH_4 ppm			
CO ppm			

CALIBRATION CHART

Date ________________ Location __________ Trailer S/N __________ Site __________

HC/CO Gas Chromatograph Make ______________ Model ____________

S/N ______________



Calibration Gas (ppm)

Calib. Base	Span	Zero	Remarks
THC ppm			
CH_4 ppm			
CO ppm			

APPENDIX D

AeroVironment Daily Check List

C 'C LIST LOG

Project No. ____________

Location ____________ Site No. ________ Month ____________ Year ____

JBJECT	ITEM	REFERENCE	TOLER.	1	2	3	4	5	6	7	8	9	:
ENERAL	Day	-	-										
	Time	MST	-										
	Temp. min. /max.	68° F/86° F	-										
ERVICE DUE:	Glass Wool	Clean	√										
AS SUPPLY	HC H_2 Supply	>500 psig	-										
	Sulfur H_2 Supply	>500 psig	-										
	Ethylene (C_2H_4)	>100 psig	-										
	Nitric Oxide (NO)	>500 psig	-										
	HC/CO Cal Gas-High	>200 psig	-										
	HC/CO Cal Gas-Low	>200 psig	-										
	HC/CO Clean Air System	Operational	-										
ECORDER	Trace	Clear	√										
	Time Marking	-	√										
	Chart Change?	End-of-chart indicator	-										
)/NO_x ANALYZER	Status	Operational	-										
	Vacuum	in Hg											

(Columns 1–: are headed STATION CHECK.)

O/NO$_x$ ANALYZER (continued)	Oven Temp.	Regulated	-										
	Drying Cartridge	>2"	-										
	NO/NO$_x$ Range	0.5/0.5 ppm	-										
	Last Zero/Span Time	MST	-										
	Last NO Zero	ppb											
	Last NO$_x$ Zero	ppb											
	Last NO Span	ppb											
	Last NO$_x$ Span	ppb											
	Data Comparison Meter/Computer/Chart	Agree	-										
$_3$ ANALYZER	Status	Operational	-										
	Range	0.5 ppm	-										
	Air Flow	lpm	-										
	C_2H_4 Pressure	psig	-										
	Last Zero/Span Time	MST	-										
	Last Zero	ppb											
	Last Span	ppb											
	Data Comparison Meter/Computer/Chart	Agree											
O_2 ANALYZER	Status	Operational	-										
	Air Flow		-										
	H_2 Flow		-										

O_2 ANALYZER (continued)	Flame	On	-										
	Test	%	-										
	Last Zero/Span Time	MST	-										
	Last Zero	ppb											
	Last Span	ppb											
	Data Comparison Meter/Computer/Chart	Agree	-										
S ANALYZER	Status	Operational	-										
	Air Flow		-										
	H_2 Flow		-										
	Flame	On	-										
	Test	%	-										
	Last Zero/Span Time	MST	-										
	Last Zero	ppb											
	Last Span	ppb											
	Data Comparison Meter/Computer/Chart	Agree											
C/CH_4/CO ANALYZER	Status	Operational											
	Carrier Flow												
	Sample Flow												
	Burner Air Flow												

HC/CH_4/CO ANALYZER (continued)	H_2 Pressure												
	Sample Pressure												
	Column Pressure												
	Total Column Pressure												
	Range THC/CH_4/00												
	Catalyst Temp.												
	Oven Temp.												
	Last Zero/Span Time	MST.	-										
	Last THC Zero/Span	ppm											
	Last CH_4 Zero/Span	ppm											
	Last CO Zero/Span	ppm											
	Data Comparison Meter/Computer/Chart												
HI-VOL SAMPLER	Status	Operational	-										
METEOROLOGICAL	Tower Lights	Working	✓										
	Cup/Vane	Normal	✓										
	Wind Speed Comparison	Normal	✓										
	Wind Direction Comparison	Normal	✓										
	Temperature	Normal	✓										
	Delta Temp.	Working	✓										

METEOROLOGICAL (continued)	RH Hygrograph	Operational	√										
	Barometer	Normal	√										
	Solar Radiation	Normal	√										
	Data Comparison Computer/Chart	Agree	-										
TECH. INITIAL:	-	-	-										
MISCELLANEOUS													

APPENDIX E

AeroVironment Data Quality

Control Chart

INSTRUCTIONS FOR FORM F047

(DATA QUALITY CONTROL CHART)

I. Fill in project, site, parameter, instrument and unit of measure. Use one sheet for each parameter.

II. Enter date and record the span and zero readings for that date.

III. Enter average by averaging the readings of that date and the previous date.

IV. Plot the calculated span and zero averages on the span average and zero average charts, respectively.

V. Make an entry in the remarks column, in abbreviation, and in the station log in more detail, a description of any corrective action performed. Abbreviations such as CA for calibration and MT for maintenance are sufficient. No entry is necessary when no action is required.

INTERPRETATION OF CONTROL

1. The instrument is out-of-control when any of the following situations arise:

   a. One or more points outside the upper control limit (UCL) or lower control limit (LCL).

   b. A run of 2 or more consecutive points outside the upper warning limit (UWL) or lower warning limit (LWL).

   c. A run of 7 or more consecutive points in a non-random manner. This might be a run up or run down or simply a run above or below the central line on the control chart.

   d. Cycles or other non-random patterns in the data.

2. When the instrument is out-of-control, corrective action such as calibration, maintenance, repair, etc. is required.

NOTE: An example is given on the following page to depict the above mentioned instructions and interpretations.

DATA QUALITY CONTROL CHART

Project ______________________ Parameter ______________________

Site ______________________ Instrument ______________________

Technician ______________________ Unit of Measure ______________________

Date																	
SPAN	Read																
	Avg.																
ZERO	Read																
	Avg.																

SPAN AVERAGE

ZERO AVERAGE

Remarks																

NOTE: ALL DETAILED REMARKS TO BE ENTERED IN THE STATION LOG

APPENDIX F

Instrument Status Report Form

C-b SHALE OIL VENTURE

Weekly Air Monitoring System Status Report

Site No. 020 Reporting Date ________ By ________

Component	Status O	Status NO	Reason/Action	Service OUT	Service IN
Bendix G. C.					
Meloy SO_2					
Meloy H_2S					
Meloy O_3					
M. L. NO/NO_x					
Meloy Calibrator					
ML DAS 9300					
Kennedy Tape					
Multi-Point					
DAS					
Hi-Vol					
Acoustic Radar					
WS/WD - 10M					
Temp. 10M					
Other:					

STATUS: (O) Operational; (NO) Non-Operational, on reporting date.
[Note in reason/action column, all major NO status during week]

REASON/ACTION: Nature or cause of malfunction and recommended or performed action taken.

SERVICE: Date of malfunction (OUT) and expected date of return-to-service (IN).

C-b SHALE OIL VENTURE

Weekly Air Monitoring System Status Report

Site No. 023 Reporting Date ____________ By ____________

Component	Status O	Status NO	Reason/Action	Service OUT	Service IN
Bendix G. C.					
Meloy SO_2					
Meloy H_2S					
Meloy O_3					
ML NO/NO_x					
Meloy Calibrator					
ML DAS 9300					
Kennedy Tape					
Multi-Point #1					
Multi-Point #2					
Hygrometer					
aro. Press.					
Solar Radiation					
Precipitation					
Hi-Vol					
WS/WD 10M					
30M					
60M					
Temp. 10M					
30M					
60M					
Delta-T 10M-60M					
Bi-Vane 10M					
60M					
Sigma-W 10M					
60M					
Other:					

STATUS: (O) Operational; (NO) Non-Operational, on reporting date.
[Note in reason/action column, all major NO status during week]
REASON/ACTION: Nature or cause of malfunction and recommended or performed action taken.

C-b SHALE OIL VENTURE

Weekly Air Monitoring System Status Report

Site No. 024 Reporting Date ________________ By ____________

Component	Status O	NO	Reason/Action	Service OUT	IN
Meloy SO_2					
Meloy H_2S					
Meloy Calibrator					
Computer					
Cassette Drive					
Teletype					
DAS					
Hi-Vol					
WS/WD 10M					
Temp. 10M					
General:					
Fire Exting.					
First Aid					
Tlr. Cond.					
Sample System					

TATUS: (O) Operational; (NO) Non-Operational, on reporting date.
[Note in reason/action column, all major NO status during week]
EASON/ACTION: Nature or cause of malfunction and recommended or performed action taken.
ERVICE: Date of malfunction (OUT) and expected date of return-to-service (IN).

C-b SHALE OIL VENTURE

Weekly Air Monitoring System Status Report

Site No. 042/056 Reporting Date ________________ By ____________

Component	Status O	Status NO	Reason/Action	Service OUT	Service IN
042 ---					
WS/WD 10M					
Temp. 10M					
Hi-Vol					
Field Gen.					
056 ---					
WS/WD 10M					
Temp. 10M					
Hi-Vol					

STATUS: (O) Operational; (NO) Non-Operational, on reporting date.
[Note in reason/action column, all major NO status during week]

REASON/ACTION: Nature or cause of malfunction and recommended or performed action taken.

SERVICE: Date of malfunction (OUT) and expected date of return-to-service (IN).

9.0

APPENDIX 9.0

Regional Impact as a Result of the Project

SOCIOECONOMIC ANALYSIS

FOR

DOE ALTERNATE FUELS PROPOSAL

Submitted To:

OCCIDENTAL OIL SHALE, INC.

Pace Quality Development Associates, Inc.
Cherry Creek Plaza II
650 South Cherry Street
Suite 400
Denver, Colorado 80222

Revised November, 1980

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SOCIOECONOMIC - SUMMARY

The Cathedral Bluffs Shale Oil Project has placed an emphasis on socioeconomic factors since the project's inception. The first "Socioeconomic Assessment" for the project was completed along with the original Detailed Development Plan. As the scope and magnitude of the C-B Project has changed, socioeconomic data has been continuously updated, and an overall corporate program for addressing socioeconomic concerns has evolved. A detailed analysis of socioeconomic factors related to a 94,000 BPD shale oil project at the C-B site is attached as a separate volume. Major findings and conclusions of that analysis are presented here.

Recognizing that special efforts would be needed to recruit and maintain a work force in the isolated area of the Piceance Basin, the C-B Project was the first shale oil project to implement a bus system for transporting all of its employees from nearby communities to the project site. The busing of employees has removed traffic from local roadways, and saved fuel and roadway maintenance costs. The C-B Project plans to continue bussing all employees from their place of residence to the site, as the labor force expands.

The C-B Project has also provided housing for employees migrating to the vicinity of the project site. Currently, the Project leases 100 apartment and condominium units, and owns 105 mobile home spaces. Plans call for the expansion of the mobile home park to 300 spaces in 1981. Project housing is currently made available to local service workers, such as teachers and municipal workers, when it is not needed by C-B employees.

Project personnel have worked closely with local government officials in recent years to plan for local growth and development and to solve specific socioeconomic concerns. The C-B Project financed the completion of Development Guides for the communities of Rifle and Meeker, in order that local officials could better understand how to manage rapid population growth. The Project, through its planning consultants, has organized local impact

mitigation teams, consisting of industry and local government leaders. The function of these teams is the exchange of current information concerning industrial and public projects, and the initiation of joint actions to address socioeconomic concerns. Technical assistance has also been provided to a variety of local government agencies for such projects as; a hospital master plan, structuring a sales tax proposal, forming a recreation district, preparing a recreation master plan, designing and tabulating a household survey, and developing a low cost housing project. The C-B Project sponsors the preparation, on a quarterly basis, of a socioeconomic monitoring report, which provides government officials with current information concerning the project work force and socioeconomic conditions within nearby communities. A copy of the most recent Cathedral Bluffs Shale Oil Project Socioeconomic Monitoring Report is contained in the appendix to the socioeconomic volume.

In summary, the following conclusions are made concerning the social and employment impacts of the proposed project; and the adequacy of existing community infrastructure to support the project:

- Employment and population growth in nearby small communities will occur at rapid rates during project construction. Other proposed industrial projects in the vicinity may contribute substantially to the employment buildup.

- Due to the small size of the local labor force and the low rate of unemployment, much of the project labor force will come from outside the immediate vicinity. Many of the project construction workers are expected to commute from other areas of Western Colorado.

- Water and sewage treatment facilities in the communities of Rifle, Meeker and Silt have been oversized to accommodate population growth. This excess capacity should lessen the initial strain of population growth upon these communities.

- School district enrollment is very near capacity in the Rifle School District, while in Meeker there is excess school capacity. New school facilities will need to be built in both communities to accommodate population growth.

- Both local hospitals are experiencing low levels of occupancy and can accommodate substantial additional growth.

- Developable land is available within existing communities to accommodate requirements for new housing. The rate of local housing development should increase greatly.

- Wages paid directly and indirectly by the Project will greatly increase the economic base of the project area.

- Tax revenues contributed by the project will exceed local government costs of service expansion in Rio Blanco County and the Meeker RE-1 School District. Garfield County governments and the Town of Meeker will require some outside assistance for service expansion over the short term.

- The Colorado Oil Shale Trust Fund, of which the C-B Project is one of two contributors, will continue to be a principal source of short term financial assistance to the affected local governments.

No impacts to tribal or other religious practices or sites are anticipated to result from the project.

The most serious adverse impact to local communities will be the lag in public revenues relative to the public costs of expanded services in those entities which will not benefit directly from the new industrial tax base. This revenue lag is created somewhat by the economic system, and somewhat by the methods of ad valorem tax collection. Property tax revenues collected on new construction generally lag one to two years behind the time construction is completed. The opening of new commercial establishments, which create the base for retail sales tax revenues, also lag behind employment in the industrial sector.

These lags are especially critical in rapid growth situations where the increased demand for government services is immediate. The only remedy for this problem is to provide short term financing for expanded local government facilities. It is logical that state and federal levels of government along with industry should provide this short term financing. Mechanisms for industry participation would include; prepayment of taxes, loan guarantees, bond guarantees, bond purchases and direct cash subsidies. Subpart F, of the Alternative Fuel Demonstration Program Regulations, enables the Secretary of DOE to provide certain government financial guarantees, which could substantially minimize the short term financing problem. The Cathedral Bluffs Shale Oil Venture is willing to work with all levels of government to address this short term financing problem.

The socioeconominc mitigation program supported by the C-B Project is detailed in the socioeconomic volume. In summary, it involves the following actions:

- Provision of a full range of information, data and forecasts concerning the project work force to government officials. This information is currently provided on a quarterly basis in the project socioeconomic monitoring reports.

- Technical assistance to local government agencies for planning and economic development activities.

- A recruitment and training program, oriented toward training local persons for employment and recruiting other employees who feel most compatable with the local way of life.

- A busing program to transport all employees from their community of residence to the project site.

- A housing program to provide employee and secondary service worker housing.

- A commitment to continue working closely with government officials to mitigate socioeconomic concerns as they arise.

SOCIOECONOMICS - THE BASE CONDITION

The location of the Cathedral Bluffs Project site will focus socioeconomic effects primarily upon communities in Western Garfield County and Eastern Rio Blanco County. (See Figure 1) This assumption has been substantiated by the residency patterns of current project workers, as reported in the Quarterly Cathedral Bluffs Shale Oil Project Socioeconomic Monitoring Report (See Appendix A). The majority of project workers are expected to reside in Rifle, while most other workers are expected to reside in Meeker or Silt. A small percentage of project workers are expected to reside in other communities in the region such as: New Castle, Parachute, and Rangely.

Because of their location, these communities have anticipated rapid population growth, caused by energy resource development, since the early 1970's. But delays in the development schedules of nearby oil shale and coal projects have delayed the population build-ups, so that growth rates have been moderate in recent years, and local governments have had an opportunity to expand public services and facilities.

EMPLOYMENT AND POPULATION

Employment in both Garfield and Rio Blanco Counties has increased in recent years. As shown in Table A total employment increased by 7.7 percent in Garfield County, and by 17.1 percent in Rio Blanco County from 1977 to 1979. Employment distributions in the two counties are displayed in Table B. Employment in Garfield County is concentrated in wholesale and retail trade, government and services. Government is a major employer in Rio Blanco County, as is mining. The majority of current mining employment in Rio Blanco County is associated with oil and gas exploration.

Future employment and population growth in the two counties are highly dependent upon the development of the area's energy resources. Trend population projection figures, displayed in Table C indicate a relatively slow rate of growth for the two counties and the communities of Rifle, Meeker and Silt from 1980-1990. The trend figures reflect no major energy project development.

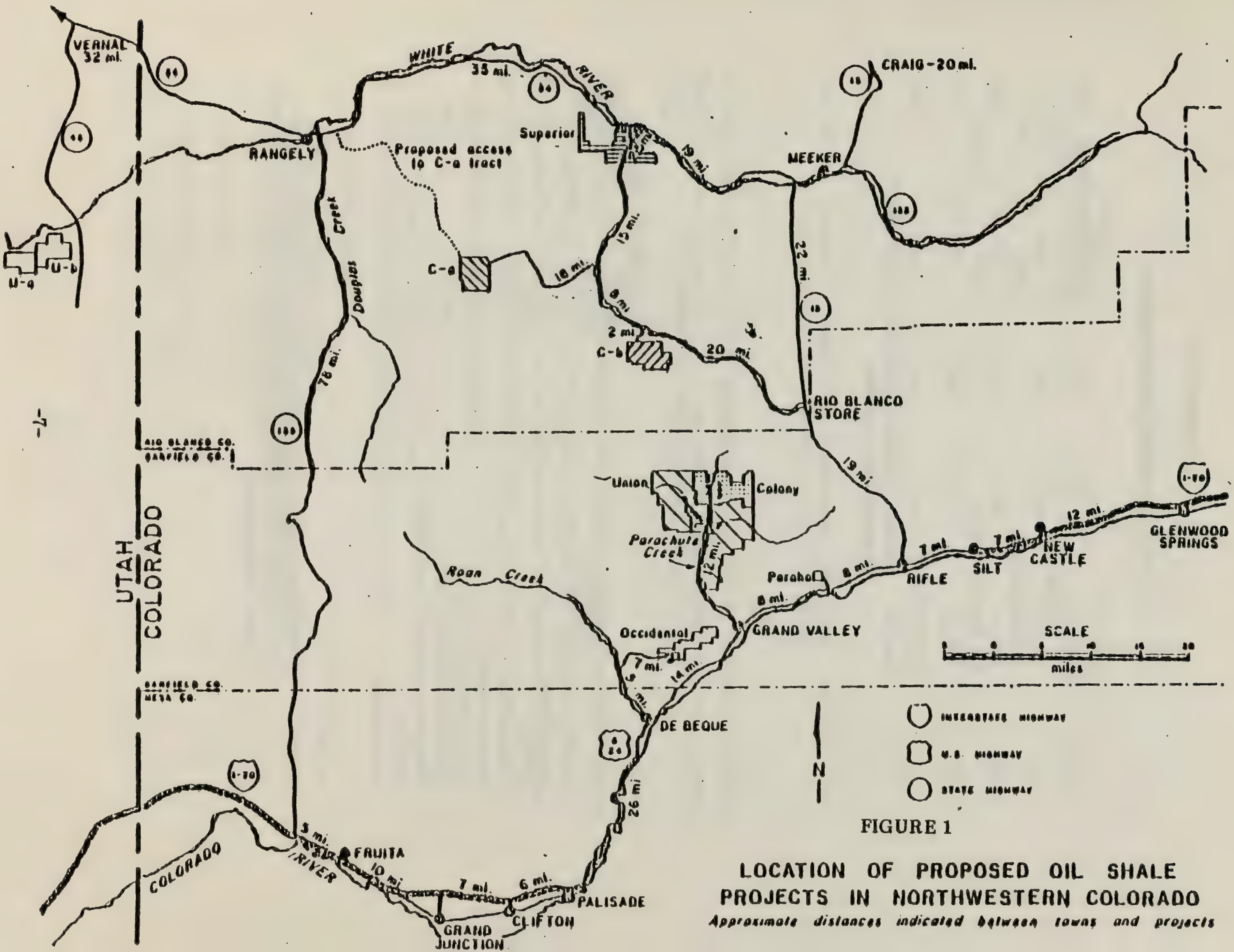


FIGURE 1

LOCATION OF PROPOSED OIL SHALE PROJECTS IN NORTHWESTERN COLORADO

Approximate distances indicated between towns and projects

TABLE A

COUNTY EMPLOYMENT

County	Total Employment 1977	Total Employment 1979
Garfield County	9,946	10,715
Rio Blanco County	2,161	2,531

Source: State of Colorado, Division of Employment Research and Analysis

TABLE B

COUNTY EMPLOYMENT BY INDUSTRY

Industry	% of Total Employment: Garfield County	% of Total Employment: Rio Blanco County
Agriculture	12.6	5.7
Mining	N.A.	26.6
Construction	9.4	8.8
Manufacturing	2.5	2.7
Transportation, Utilities	8.8	9.5
Wholesale: Retail Trade	26.1	9.9
Finance, Insurance, Real Estate	3.7	3.2
Services	18.1	5.5
Government	18.8	28.1

Source: Final West-Central Colorado Coal E.S., U.S. Bureau of Land Management, and Northwest Supplemental Report U.S. Bureau of Land Management.

TABLE C

TREND POPULATION GROWTH

Year	Garfield County	Rifle	Silt	Rio Blanco County	Meeker
1977	18,800	2,244	859	5,100	1,848
1980	19,985	2,316	896	5,324	1,886
1985	23,178	2,448	977	5,710	1,958
1990	25,823	2,585	1,066	6,067	2,044

Source: Region XI Population Projections 1980-2000, Colorado West Area Council of Governments, September 1980.

If employment associated with proposed energy projects (including Cathedral Bluffs) is added to the trend data, population growth projections are adjusted upward.

Population projections which consider most energy resource projects proposed for development in Garfield and Rio Blanco Counties, are displayed in Table D. These projections were prepared by the local council of governments, and they are recognized as official projections for the region. They include manpower requirements for the following projects:

- C-B Cathedral Bluffs Shale Oil Company
- C-a Rio Blanco Oil Shale Project (Gulf and Standard)
- Paraho (oil shale)
- Snowmass/Anschutz (coal)
- Mid-Continent. Garfield/Mid-Continent Mesa II (coal)
- Superior (oil shale and minerals)
- ColoWyo (coal)
- Utah International (coal)
- Colorado Ute (power plant)

TABLE D

CUMULATIVE NEW ENERGY INDUSTRY EMPLOYMENT

	1980	1981	1982	1983	1984	1985	1990	1995	2000
Colony	200	650	1900	3000	3250	2200	1450	1450	1450
Union		400	663	743	743	743	1395	1395	1395
C-a		450	600	1200	2500	3400	3700	3500	3500
C-b	450	600	1200	2500	3400	3500	3700	3500	3500
Superior			104	169	494	780	377	377	377
Snow Mass/Anschutz	35	75	125	125	125	125	125	125	125
Colo-Wyo.	0	120	224	373	429	429	429	429	429
Nothern Minerals	150	235	360	380	400	430	570	670	670
New Coal Leasing & Expansion				260	260	963	963	963	963
Colo. Ute	200	400	500	300	-1150	-1150	-1150	-1150	-1150
GEX/CMC	221	241	289	297	325	335	400	400	400
Sheridan	177	202	287	342	397	475	475	475	475
Mid Cont. Mesa II			72	140	160	207	207	207	207
Moon Lake I		282	329	537	481	414	414	414	414
Moon Lake II		396	513	884	691	474	474	474	474
Storm King	150	150	150	150	150	150	300	300	300

Source: Colorado West Area Council of Governments

Empire (coal)
Moon Lake (coal)
GEX CMC (coal)
Sheridan (coal)
Energy Fuels (coal)
Union Oil (oil shale)
Storm King (coal)
Colony/Exxon USA and TOSCO (oil shale)
Northern Minerals (coal)
New Coal (new leasing and expansions as proposed as part of BLM's Hams Fork E.S.)

Employment projections for each project are included in Table D.

The population projections in Table E reflect high growth rates in Rifle and Meeker for the period 1980-1985, and a moderate rate of growth in Silt. Meeker is projected to increase in population at an average annual rate of 32.5 percent, Rifle at an average annual rate of 37.8 percent and Silt at an average annual rate of 17.0 percent.

It will be difficult to construct necessary housing and public facilities to accommodate these growth rates if they do occur. The follwing analysis attempts to consider socioeconomic factors associated with both levels of population growth. The uncertainty associated with energy project development, and synthetic fuels projects in particular, is likely to result in actual growth occurring in the middle range.

LOCAL GOVERNMENT JURISDICTION

A number of local government entities will be affected by the development of the Cathedral Bluffs Project including: counties, municipalities, school districts and special purpose district. The project site is within the jurisdiction of Rio Blanco County and the Meeker RE-1 School District. These are the only two local government jurisdictions which will receive direct property tax benefits as a result of the project. Garfield County, the Towns of Meeker, Rifle, Silt, and the Garfield School District RE-2 are all located within the vicinity of the

TABLE E

POPULATION GROWTH WITH PROPOSED ENERGY PROJECTS

Year	Garfield County	Rifle	Silt	Rio Blanco County	Meeker
1977	18,800	2,244	859	5,100	1,848
1980	23,013	3,933	1,079	6,111	2,615
1981	27,837	5,661	1,268	9,230	3,650
1982	36,494	8,492	1,547	12,002	4,861
1983	45,440	12,516	1,943	14,343	7,031
1984	53,265	18,113	2,297	16,806	9,077
1985	55,694	19,573	2,361	19,392	10,693
1990	64,379	23,710	2,595	25,703	24,179

Source: Region XI Population Projects 1980-2000, Colorado West Area Council of Governments

project. The sanitation district in Meeker, the hospital district in Rifle and various other special purpose districts also exist within the vicinity of the project.

PUBLIC SERVICES AND FACILITIES

Each of the communities in the project area have upgraded their capacity to provide public services and facilities in recent years.

The City of Rifle currently operates two water treatment plants: the Graham Mesa Treatment Plant and the Beaver Treatment Plant, located south of the city. In addition to the two treatment facilities, there are presently four storage facilities, including a recently completed 3.0 million gallon tank. The water system expansion program which is underway in Rifle, and is schedule to be completed by the end of 1981, will provide for growth up to 10,000 persons.

Meeker's water system was upgraded in 1976, and at current usage rates, it can provide for a population of up to 4,000 persons. Silt has recently begun construction on a $1.4 million program to upgrade its water system. Improvements should be completed by 1981, at which time the water system will have a design capacity of 2,800 persons.

The municipal sewage treatment facility in Rifle is currently operating beyond design capacity. However, plans are now being finalized to expand the facility to a treatment capacity of 1.04 million gallons per day, which would accommodate a population of about 10,000 persons. The Rifle Village South Metropolitan District operates a lagoon treatment system which is currently capable of treating sewage for about 1,200 persons. This treatment system is capable of being expanded to twice that capacity as the need arises.

The sewage treatment system in Meeker is currently capable of accommodating a population of up to 4,000 persons. Silt is in the process of designing a new sewage treatment plant which could serve up to 2,800 persons.

With water and sewage facilities which are either in place, or are scheduled for construction in the near future, Rifle could accommodate up to 10,000 persons, Meeker up to 4,000 and Silt up to 2,800.

Transportation has been a major concern to the three communities in their efforts to accommodate rapid growth. Rifle is planning a bypass route to relieve traffic congestion from Colorado 13 as it passes through town. A shortage of about $1 million currently exists in funds needed to complete the bypass project. Rifle is also attempting to procure funding for a major street improvement and storm drainage project. Meeker is in the process of upgrading and improving drainage along Colorado 13, west of town. Silt, which presently is without any paved streets, is seeking $2.7 million to pave the majority of streets in town.

Health care in the area is provided through Pioneer Hospital in Meeker and Clagett Memorial Hospital in Rifle. Both hospitals are presently utilized well

below capacity, but both hospitals are planning for rapid expansion once the need arises. In some areas, such as emergency room services, the demand upon medical services has already required that expansion take place. An increase in the number of physicians in the area has also occurred recently.

Other minicipal services have been increasing steadily as population increases in the three communities. Rifle and Meeker have expanded their law enforcement staffs in the last year. Meeker has acquired additional firefighting equipment. Rifle has added two additional municipal staff members, a recreation director and a planning director. Silt has added a planner, but continues to be short of personnel in the areas of law enforcement and public works.

Annual public sector revenues and public sector costs, based upon energy growth, are projected for the two counties and the communities of Rifle and Meeker in Tables F and G. Rio Blanco and Garfield Counties as well as the towns of Rifle and Meeker are expected to experience revenue surpluses throughout the period 1980-1990.

Municipal revenue from retail sales taxes may be significantly understated in this analysis because it is computed based upon historical shopping patterns. The small size of each of these communities has limited the quantity and variety of retail merchandise available in the past, causing income "leakage" from the community. As the communities grow in size, retail sales (deflated) should increase at a faster rate than population, providing a higher level of retail sales tax income to municipal governments. This relationship has been demonstrated in many small communities. Craig, Colorado, which has experienced population growth of an estimated 10 percent per year in the past two years, experienced an increase in retail sales of 32 percent in 1979.

TABLE F

COUNTY REVENUE AND EXPENDITURE ANALYSIS – BASED ON PROPOSED ENERGY GROWTH
(Constant 1980 Dollars – $M)

	Garfield County							Rio Blanco County						
	1980	1981	1982	1983	1984	1985	1990	1980	1981	1982	1983	1984	1985	1990
Revenue	7,634	9,537	12,621	16,881	23,314	29,474	38,890	6,117	6,938	10,029	14,299	19,312	21,730	25,071
Expense	5,366	6,047	7,491	9,424	10,974	12,799	15,938	5,729	6,285	8,753	11,879	15,378	16,697	18,752
Net Revenue (Expense)	2,268	3,540	5,130	7,457	12,340	16,675	22,952	388	653	1,276	2,420	3,934	15,033	6,319
Cumulative Revenue (Expense)	2,268	5,808	10,933	18,395	30,735	47,410	162,170	388	1,041	2,317	4,737	8,671	13,704	41,365

Source: Draft Report Oil Shale Tax Study; Peat, Marwick, Mitchell & Co.

TABLE G

MUNICIPAL REVENUE AND EXPENDITURE ANALYSIS – BASED ON PROPOSED ENERGY GROWTH
(Constant 1980 Dollars – $M)

	Rifle							Meeker						
	1980	1981	1982	1983	1984	1985	1990	1980	1981	1982	1983	1984	1985	1990
Revenue	1,715	2,167	3,514	5,581	7,226	7,436	10,431	1,585	1,776	2,472	3,947	4,873	5,606	6,248
Expense	1,637	2,032	3,332	5,194	6,716	6,755	9,510	1,282	1,436	1,999	3,192	3,941	4,534	5,053
Net Revenue (Expense)	78	135	182	387	510	681	921	303	340	473	655	932	1,072	1,195
Cumulative Revenue (Expense)	78	213	395	782	1,292	1,973	7,518	303	643	1,116	1,771	2,703	3,775	10,105

Source: Draft Report Oil Shale Tax Study; Peat, Marwick, Mitchell & Co.

Fiscal projections are not available for Silt at the present time. It is anticipated that Silt will experience similar budgetary deficits during periods of rapid growth due to its limited ability to generate tax revenues. Silt will also be at a disadvantage, because of its small size, in generating increased sales tax revenue.

PUBLIC EDUCATION

Current enrollment in the two school districts which serve the communities of Rifle, Meeker and Silt is displayed in Table H. Also displayed is the present design capacity of each school district.

TABLE H

SCHOOL DISTRICT ENROLLMENT AND FACILITY CAPACITY - 1980

District	Enrollment	Design Capacity
Garfield School District RE-2		
Elementary	1,018	1,005
Junior High	209	250
Senior High	491	490
Meeker School District RE-1		
Elementary	406	500
Junior High	130	250
Senior High	238	450

Source: Cathedral Bluffs Shale Oil Project, Socioeconomic Monitoring Report, June 1980.

The Garfield School District Operates two elementary schools, a junior high school and a senior high school, and serves the communities of Rifle, Silt and New Castle.

Enrollment in School District RE-2 has increased by 103 students over the past year, or six percent. The majority of the increase has been in elementary school students. The new high school in Rifle is scheduled to be completed in January 1981, and it will relieve some of the pressure on the secondary schools. The new high school building will be capable of accommodating 675-800 students. Plans are underway for the construction of an additional elementary school in Rifle in the near future.

The Meeker School District has completed design work for expansion of the high school and for a new elementary school. They have also completed a land swap with the city for a future elementary school site. Acquiring sites for future schools is a concern of the school district. The district has applied for a $125,000 grant which would allow them to purchase sites for additional kindergarten, elementary school and high school facilities.

The following standards indicate the requirements for school facilities in the area as population expands.

TABLE I

	Population Level					
	10,000		15,000		20,000	
	Enroll-ment	Schools Needed	Enroll-ment	Schools Needed	Enroll-ment	Schools Needed
Elementary	1,650	3-4	2,475	5	3,300	6-7
Junior High	750	2	1,125	2	1,500	2-3
Senior High	1,650	2	2,475	23	3,300	2-3

Source: Rifle Comprehensive Framework Plan, March 1980, BMML.

HOUSING

Table J displays the expected demand for additional housing units in Rifle, Meeker and Silt from 1980-1990, given both trend population growth, and population growth with proposed energy project development.

TABLE J

HOUSING DEMAND
(Additional Dwelling Units)

Year	Trend Growth			Proposed Energy Growth		
	Rifle	Meeker	Silt	Rifle	Meeker	Silt
1980	47	12	19	143	113	67
1981	41	11	15	628	375	68
1982	41	11	16	1,029	440	101
1983	41	11	16	1,463	790	144
1984	41	11	16	2,035	744	129
1985	41	11	16	531	582	23
1986-1990	50	57	62	1,504	1,268	85

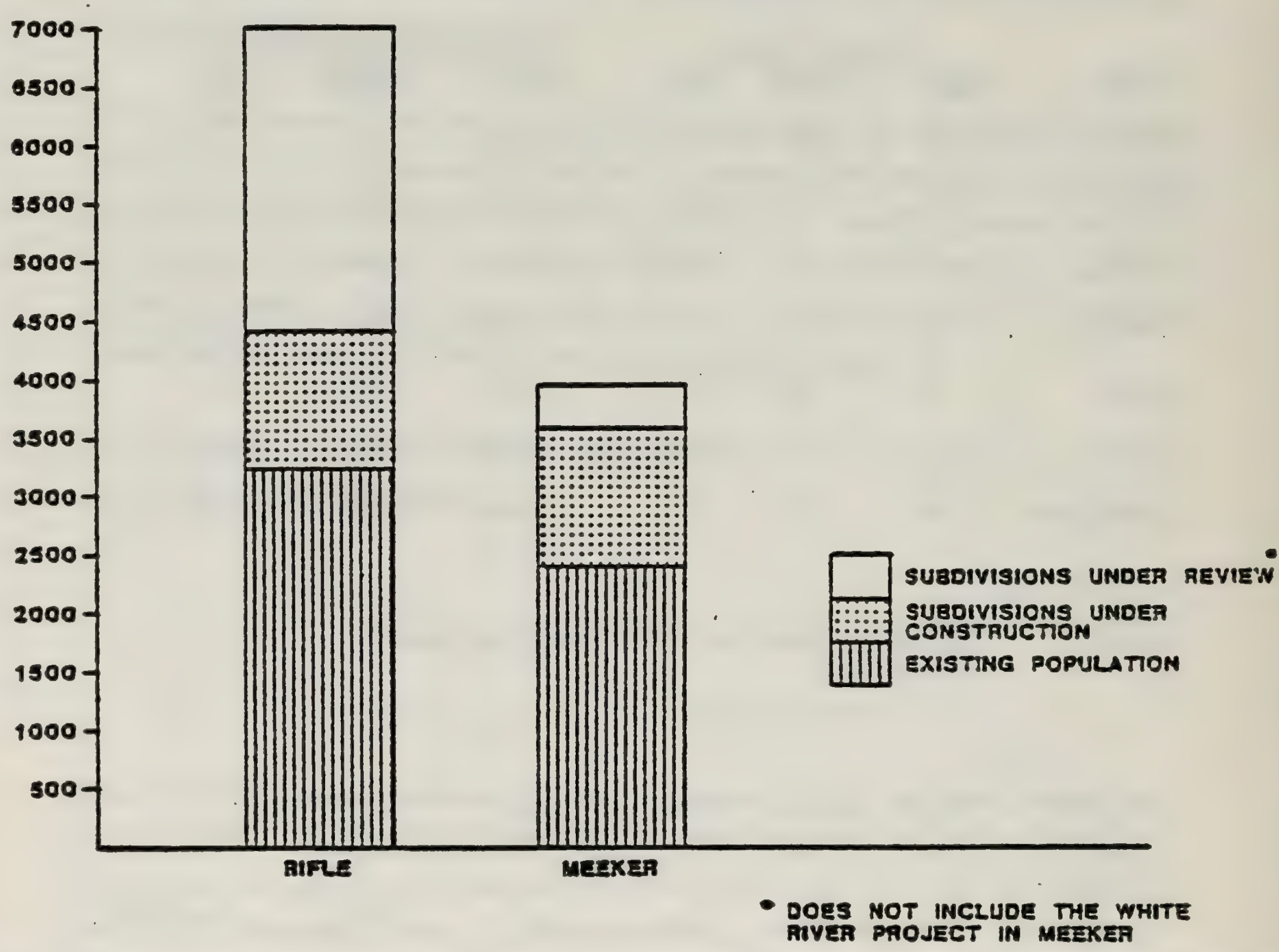
Source: Estimates based upon 2.75 average persons per housing unit

Residential construction has averaged about 120 units per year in Rifle, 30 units per year in Meeker and 10 units in Silt in recent years. This rate of construction could accommodate the trend demand for housing, but the rate of construction would have to be increased greatly in each community to provide for demand assuming energy growth projections.

Both Rifle and Meeker have a number of subdivisions under development. Figure 2 displays the capacity of land under development in terms of ability to accommodate additional population.

FIGURE 2

POPULATION CAPACITY OF RESIDENTIAL DEVELOPMENTS



It has been estimated recently that Rifle could accommodate up to 25,000 persons at an average density of five persons per acre on land available for development within the area presently served by its water and sewage treatment systems. Silt also has a large amount of developable land available. Limitiations to housing development in Silt as in Rifle and Meeker will be through public services rather than available land.

SOCIOECONOMIC IMPACTS OF THE SHALE OIL PROJECT

This section analyzes the socioeconomic effects of the project upon the surrounding region. An attempt is made to differentiate between the effect of temporary (construction) employment and permanent (operations) employment.

EMPLOYMENT AND POPULATION GROWTH

Figure 2 displays project manpower requirements. These manpower requirements are used to project the total employment and population growth increases in the region shown in Tables K and L. It is assumed in these projections that the characteristics exhibited by the current construction work force will continue throughout the construction period. These characteristics are documented in the Cathedral Bluffs Shale Oil Project Socioeconomic Monitoring Report. (See Appendix) Assumptions made concerning employment and population growth include the following:

- Construction work force is 50 percent married with families present, 15 percent married without families present, 35 percent single (Source: Cathedral Bluffs Shale Oil Project Socioeconomic Monitoring Report).
- Operations work force is 75 percent married with families present, 25 percent single (Source: Esitmates based on data from Cathedral Bluffs Shale Oil Project monitoring program).
- Average family size of married construction workers is 3.1 persons, while average family size of married operations workers is 3.3 persons (Source: Cathedral Bluffs Shale Oil Project monitoring program).
- Additional local employment generated by construction employment will be at a ratio of .5 to 1 (Source: The Moffat County Capital Improvements Development Program).
- Additional local employment generated by project operation will be at an initial rate of .7 to 1, rising to .9 to 1 in 1990 and later.
- 40-50 percent of service sector jobs will be filled by a second wage earner in a two wage earner household.

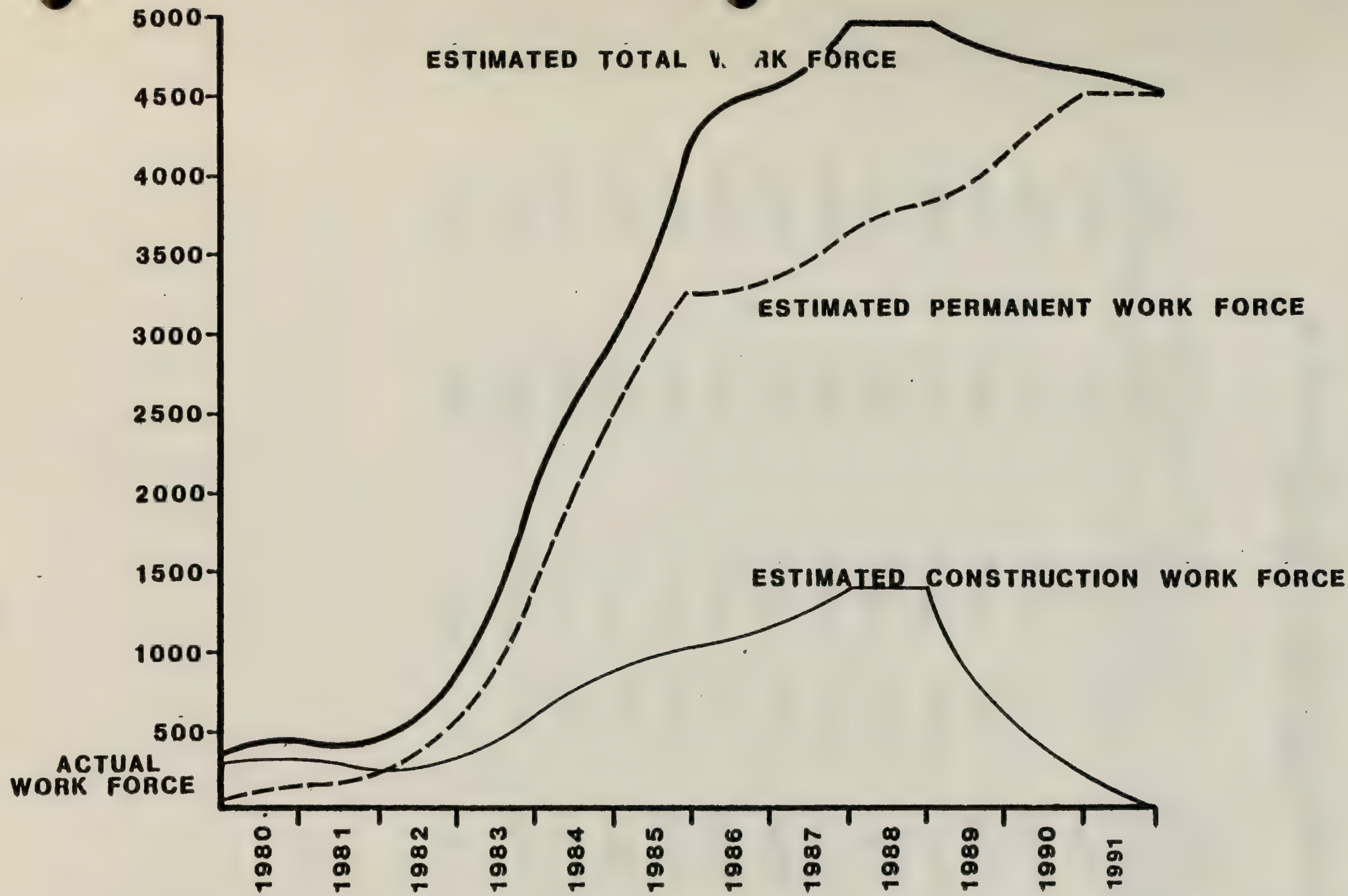


FIGURE 3 **CATHEDRAL BLUFFS SHALE OIL PROJECT MANPOWER REQUIREMENTS**

Construction Manpower	290	335	147	420	610	890	1040	1190	1410	1140	610	230	0
Permanent/ Operation Manpower	50	115	216	560	1410	2030	3230	3330	3550	3830	4150	4430	4430
Total Manpower	340	440	363	980	2020	2920	4270	4520	4960	4970	4760	4660	4430
End of Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991

TABLE K

PROJECTED LOCAL EMPLOYMENT INCREASES AS A RESULT OF THE PROJECT

	PROJECT CONSTRUCTION EMPLOYMENT	PROJECT OPERATIONS EMPLOYMENT	SECONDARY SERVICE EMPLOYMENT	TOTAL EMPLOYMENT
1979	290	50	180	520
1980	335	115	230	680
1981	147	216	220	583
1982	420	560	550	1,530
1983	610	1,410	1,290	3,310
1984	890	2,030	1,870	4,790
1985	1,040	3,230	2,780	7,050
1986	1,190	3,330	3,260	7,780
1987	1,410	3,550	3,540	3,500
1988	1,140	3,830	3,630	8,600
1989	610	4,150	3,630	8,390
1990	230	4,430	4,100	8,760
1991	0	4,430	3,990	8,420

TABLE L

PROJECTED LOCAL POPULATION INCREASES AS A RESULT OF THE PROJECT

	RIFLE	MEEKER	SILT	OTHER AREAS	TOTAL
1979	655	170	100	95	1,020
1980	825	245	130	105	1,305
1981	885	290	140	105	1,420
1982	1,835	655	300	195	2,985
1983	4,255	1,565	695	435	6,950
1984	6,150	2,250	1,005	630	10,035
1985	9,080	3,420	1,490	895	14,885
1986	10,080	3,785	1,650	1,000	16,515
1987	11,015	4,095	1,800	1,105	18,015
1988	11,165	4,255	1,835	1,080	18,335
1989	10,925	4,340	1,805	990	18,060
1990	11,430	4,680	1,900	980	18,990
1991	10,995	4,530	1,835	915	18,325

- Employees in the support sectors will be 80 percent married and 20 percent single (Source: The Moffat County Capital Improvements Development Program).
- Average family size of employees in the support sectors is 3.3 persons (Source: The Moffat County Capital Improvements Development Program).

Whenever possible, these assumptions reflect actual data collected from the Cathedral Bluffs Project during the past two years.

Location of the project will influence most project workers to reside in one of the three nearby communities of Rifle, Meeker, or Silt. Rifle is the closest community to the project site, at a distance of 41 highway miles, while Meeker is 44 miles and Silt is 48 miles from the site. Currently, 63 percent of the workers on the Cathedral Bluffs site reside in Rifle, with 11 percent residing in Meeker and 5 percent residing in Silt. The remaining workers are distributed among other towns in the area such as: New Castle, Glenwood Springs, Grand Valley and Grand Junction. (See Appendix) This distribution refers to workers who are engaged primarily in construction activity. The primary reason for this distribution is the availability of housing in Rifle and its proximity to larger urban areas.

Residency patterns exhibited by the current work force are expected to remain consistent as the construction work force expands. A residency distribution of 65 percent in Rifle, 15 percent in Meeker, 10 percent in Silt and 10 percent in other areas (New Castle, Glenwood Springs, Grand Valley and Grand Junction) is assumed for construction workers.

The residency pattern of permanent project workers is expected to vary somewhat from construction workers. Permanent workers are expected to place more value on proximity of place of work, and established community than are temporary workers. for these reasons, the distribution of the permanent work force is assumed to be 60 percent in Rifle, 25 percent in Meeker, 10 percent in Silt and 5 percent in other locations.

Table L is a projection and allocation of local population increase as a result of the project. These population figures include both project workers and derived secondary service employees.

The greatest effects of population growth due to the project should be in the community of Rifle. These figures assume that a large percentage of the construction work force will be housed in Rifle, an assumption which could change substantially if construction camp housing is made available. Population increases in Meeker and Silt should not be nearly as large as in Rifle, but incoming population would significantly increase the existing size of those two communities.

LABOR SUPPLY

Project operation will require a large number of skilled workers which are not currently available in the local labor force. To address the labor force needs, the Cathedral Bluffs Project is developing a sophisticated system of labor recruitment and training.

The Cathedral Bluffs Project intends to make training programs available, either in-house or through local education institutions, which will qualify individuals for all skills required in project operation. This will enable many local residents to obtain employment with the project. It should also allow for more long-term opportunities for construction workers in the area to obtain permanent project employment, which would reduce the movement of persons in and out of the local area as the transition is made from construction to operations.

PUBLIC FACILITIES AND SERVICES

The ability of local government public facilities and services to provide for future demand is highly contingent upon the rate of total population growth in the region. The uncertainty of population growth is caused by the uncertain development schedule of energy resource projects other than the Cathedral Bluffs Project, and upon which the Cathedral Bluffs Project has little control.

As indicated in the previous section the communities of the region are working to expand facilities and services. Rifle is completing a comprehensive plan which closely examines all aspects of accommodating a population of 10,000 persons. Construction is currently underway to upgrade municipal water and sewage treatment facilities to accommodate up to 10,000 persons. Planning has recently begun to expand these systems even further. This construction is financed primarily through federal and state grants. Rifle is continuously expanding its law enforcement and fire protection capacity with the addition of staff and acquisition of equipment. The hospital in Rifle is currently operating at a 38 percent occupancy level, which allows for a significant increase in utilization before major expansion is necessary.

The delivery of social services has been hampered recently in Rifle by inadequate financial resources. The delivery of social services generally suffer in rapid growth communities because of the greater emphasis placed on expanding physical facilities. These services are supported on a countywide or statewide basis, however, which allows them the advantage of a larger revenue base and a revenue base which benefits from industrial development.

Meeker is also planning for a greatly expanded population. A recently completed land use concept plan identifies the need to plan for a community of 8,000 persons. Water and sewer treatment facilities are capable of accommodating a population of 4,000 persons. Additional capital improvements planning is underway which addresses a population of up to 11,500 persons. The local 17-bed capacity hospital in Meeker is averaging less than 30 percent occupancy, but out-patient services are steadily increasing.

Silt will soon have adequate water and sewage treatment facilities for a population of 2,800 persons, or a population larger than that which the town is expected to attain by 1990. (See Table E).

Existing municipal facilities in all three communities are adequate to accommodate short-term growth in the area, but most excess capacity should be absorbed by 1984. Both Rifle and Meeker will require substantial facility

expansion to accommodate population growth resulting from the combination of energy resource development proposed for the region.

It is generally true that a minimum time period required for the completion of a major public works project (i.e. water system, sewage system, street, drainage) in the area is two years, if financing for the project is available. If financing for public projects continues to be available through sources such as those discussed in the following section public sector expansion should be capable of keeping pace with private sector development.

Table M reflects basic requirements for treated water, sewage treatment, law enforcement and hospital services in the communities of Rifle, Meeker and Silt, as a result of the project.

TABLE M

INCREASED DEMAND FOR MUNICIPAL SERVICES RESULTING FROM THE PROJECT 1980-1990

	RIFLE	MEEKER	SILT	OTHER AREAS
Treated Water*	3,848 MGD	1,603 MGD	.642 MGD	.320 MGD
Sewage Treatment**	1.099 MGD	.485 MGD	.183 MGD	.093 MGD
Law Enforcement***	22 officers 11 police vehicles	9 officers & 4 police vehicles	4 officers & 2 police vehicles	— — —
Hospital****	399 additional beds	13 additional beds	(Included in Rifle estimate)	—

* Based on average day consumption of 350 gallons per capita.
** Based on average day effluent of 100 gallons per capita.
*** Based on standard requirement of two officers and one police vehicle per 1,000 persons. Population based on 10,000 persons.
**** Based on standard of three hospital beds per 1,000 persons in the service area. Population based on 10,000 persons.

PUBLIC EDUCATION

Projected growth in school enrollment in each local school district resulting from the project is presented in Table N. The actual age distribution of children of current project workers, who are in-migrants to the area, were used in these calculations. The Cathedral Bluffs Socioeconmic Monitoring Reports show that children of in-migrating workers are of the following school age distribution.

Preschool	-	37%
Elementary	-	42%
Junior High School	-	12%
Senior High School	-	9%

The project would generate a substantial increase in school enrollments, particularly in the Garfield School District RE-2, where most schools are currently at capacity. Some of the increased demand upon school facilities could be reduced if employees hired during the construction phase of the project were discouraged from bringing their families to the local area. This would provide the local school districts with more lead time to plan and build additional school facilities. This could be accomplished by providing temporary housing to employees without families.

Estimated costs of expanded public services and facilities are detailed in Table O. These costs are grouped according to local jurisdiction; municipality, county or school district, which has responsibility for the particular public service.

Applying the per capital cost figures to the projected population increases due to the project, yields estimated costs of public facility and service expansion of $180,761,000 as displayed in Table P. Capital investment costs reflect an estimate based upon a permanent population of 18,325.

TABLE N

PROJECTED INCREASES IN LOCAL SCHOOL ENROLLMENT AS A RESULT OF THE PROJECT

Year	Total Students: Garfield School District RE-2*	Meeker School District RE-1	Other Areas	Total
1979	165	35	20	220
1980	225	45	30	300
1981	780	155	105	1,040
1982	1,305	260	175	1,740
1983	1,990	400	265	2,655
1984	2,990	600	400	3,990
1985	3,065	615	410	4,090
1986	3,250	650	435	4,335
1987	3,215	645	430	4,290
1988	3,245	650	435	4,330
1989	3,280	655	435	4,370
1990	3,465	695	460	4,620

*Includes Rifle and Silt

TABLE O

ITEMIZED ESTIMATES OF PUBLIC FACILITY AND SERVICE COSTS
(Per Capita Capital Costs For A Population Base of 10,000 Persons – 1980 Dollars)

			Capital Investment
Municipal Services			
1.	Water System		$ 395.00
2.	Sewage Treatment		426.00
3.	Storm Drainage		144.28
4.	Solid Waste		13.88
5.	Open Space and Recreation		372.42
6.	Government Regulation		34.63
7.	Planning		330.80
8.	Police		29.56
9.	Fire		148.17
10.	Library		73.87
11.	Health and Medical		210.84
12.	Municipal Streets & Roads		1,836.00
13.	Cemeteries		10.83
14.	Other (5% of total)		201.31
		Total	$4,227.59
County Services			
1.	County Roads & Highways		$1,035.00
2.	Mental Health		—
3.	Development Disabilities		—
4.	Physical Rehabilitation		—
5.	Social Services		1,090.00
6.	Public Health		—
7.	Elderly Services		—
8.	Juvenile Corrections		—
9.	Adult Corrections		—
10.	Other (5% of total)		227.33
		Total	$2,352.33
School District Services			
1.	Preschool		$ 170.83
2.	Elementary		1,197.34
3.	Junior and Senior High		1,225.00
4.	Vocational-Technical		834.75
5.	Higher Education		306.72
		Total	$3,734.64

Source: Oil Shale Tract C-B, Socioeconomic Assessment, Volume II Impact Analysis, C-B Shale Oil Project. Figures updated to 1980 dollars using implicit price deflators for local government expenditures.

TABLE P

ESTIMATED COST OF PUBLIC FACILITY AND SERVICE EXPANSION DUE TO PROJECT CONSTRUCTION
(1980 Dollars)

		Capital Investments
Garfield County*		$ 31,257,000
School District RE-2**		47,915,000
Rifle		46,482,000
Silt		7,758,000
Rio Blanco County		10,774,000
School District RE-1		17,105,000
Meeker		19,362,000
	Total	$ 180,653,000

* Assumes Rifle, Silt and 50 percent of growth in other areas.
** Assumes Rifle and Silt only.

HOUSING

Table Q displays the total demand for additional housing units in each community as a result of the project. These calculations assume that one housing unit will be required for each 1.5 single workers and each 1.0 married workers. Housing for employees in the support sectors is included in the calculations.

Assuming an average gross density of 5 units per acre, included in the Rifle Comprehensive Framework Plan as a target density, additional residential land requirements would be 741 acres in Rifle, 309 acres in Meeker, 122 acres in Silt and 62 acres in other areas.

TABLE Q

HOUSING DEMAND RESULTING FROM PROJECT OPERATION

Total Dwelling Units

Year	Rifle	Meeker	Silt	Other Areas
1979	235	95	40	20
1980	290	120	50	25
1981	305	130	50	25
1982	635	265	105	55
1983	1,465	610	245	120
1984	2,115	880	350	175
1985	3,110	1,295	520	260
1986	3,455	1,440	575	280
1987	3,780	1,575	630	315
1988	3,820	1,590	635	320
1989	3,710	1,545	620	310
1990	3,860	1,610	645	320
1991	3,705	1,545	610	310

The abundance of housing units which are planned for the communities of Rifle and Meeker should provide for a large portion of the housing needs in those communities during the early years of the project. Table R is a detailed account of housing projects currently under development in the two communities. Additional housing units, beyond those planned for development, will likely be needed in Rifle beginning in 1983 or 1984.

The possible development of temporary housing for construction workers, would ease the housing demand in existing communities, during the initial years of the project.

TABLE R

PLANNED RESIDENTIAL DEVELOPMENT WITHIN CATHEDRAL BLUFFS PROJECT AREA

Development	General Location	Number and Type of Units	Status
Rifle Area			
Palomino Park	N. Rifle		
Phase I		30 Apartment Units	Completed
		29 Single Family Lots	Completed
Phase II		15 Single Family Lots	14 Completed
		70 Apartment Units	40 Completed
		20 Townhouses	4 Completed
Phase III		44 Single Family Lots	18 Completed
Phase IV		47 Single Family Lots	0 Completed
		20 Apartment Units	Plats withdrawn
Phase V		42 Apartment Units	Plats withdrawn
Highlands East	E. Rifle		
Phase I		37 Single Family Lots	Completed
		10 Apartment Units	Completed
Phase II		5 Single Family Lots	1 Completed
		4 Apartment Units	0 Completed
Phase III		16 Single Family Lots	60% Completed
Phase IV		36 Single Family Lots	30% Completed
		64 Apartment Units	
Phase V		60 Single Family Lots	10% Completed
Phase VI		77 Single Family Lots (Cluster Homes)	Final plat approved
Phase VII		65 Single Family Lots	Sketch plan submitted
Arabian Heights	N.E. Rifle		
Phase I & II		27 Single Family Lots	20% Completed
Phase III		187 Single Family Lots	Sketch plan approved
		31 Duplexes	Sketch plan approved

Development	General Location	Number and Type of Units	Status
Rifle Area (Continued)			
Kings Crown Mobile Home Subdivision	N.W. Rifle		
Phase I		103 Mobile Home Spaces	75 percent occupied
Phase II		189 Mobile Home Spaces	Approved but not yet under construction
Shadow Ridge	W. Rifle	27 Single Family Lots 10 Duplexes 46 Townhouses 20 Condominiums	Final plat stage
Cottonwood Meadows	W. Rifle	250 - 400 Units, mixed residential	Sketch plan lapsed
Rimrock	N. Rifle		
Phase I		288 Condominiums 240 Apartments 223 Single Family Lots 100 Multi-Family (Duplexes and Four-Plexes)	Sketch plan stage
Phase II		Revising initial concepts	No action
Mesa View Estates	S.W. Rifle		
Phase I		34 Single Family Lots	90% Completed
Phase II		10 Single Family Lots	Preliminary plat stage
Knollridge P.U.D.	N.W. Rifle	34 Single Family Lots 52 Duplexes 100 Townhouses 168 Mutli-Family Apartments	Preliminary plat approved
North Meadows	N. Rifle	250 Multi-Family	Sketch plan approved
Rifle Heights	E. Rifle	100 Single Family	Sketch plan lapsed
Mahogany Addition	S. Rifle	48 Multi-Family Units	0 Completed
Trapper Hollow P.U.D.	W. Rifle	28 Condominium Units	0 Completed

Development	General Location	Number and Type of Units	Status
Rifle Area (Continued)			
Barnett P.U.D.	W. Rifle	20 Condominium Units	Final plat approved
Carmack Mobile Home Subdivision	N. Rifle	300 Mobile Home Lots 40 Multi-Family Units	Sketch plat approved
Creek Meadows	N. Rifle	152 Multi-Family Units	Preliminary plat approved
Fairview Addition		20 Condominiums	Sketch plan approved
Jackson Heights (Senior Citizen and subsidized housing)	W. Rifle	8 Single Family Lots 25 Condominiums 16 Cluster Houses	Sketch plan approved

COMMUNITY ECONOMIC BENEFITS

Construction and operation of the Cathedral Bluffs Shale Oil Project will contribute increased wage and salary income to nearby communities over the project life. Average construction worker wages are expected to be $27,000 annually (1980 dollars), while operations workers are expected to earn $22,000 annually (1980 dollars). These wages are significantly higher than the existing overall wage in the area. Employees in the support sectors, whose jobs are generated by project operation, are expected to earn an average wage of $15,500 annually (1980 dollars). An estimated local total payroll of $3.4 billion wil be generated directly by the project. An additional local payroll of $2.4 billion will be generated in local service sector jobs, for an estimated total local payroll of $5.8 billion. Table S is a tabulation of both direct and indirect annual local payroll generated by the project. The payroll figures are allocated by the expected residence distribution of project workers.

Local government jurisdictions will benefit from the project through increased tax revenues. The project will contribute property taxes directly to Rio Blanco County and the Meeker School District. Other entities of local government will benefit through individual property taxes, sales taxes and other local government taxes and fees.

The State of Colorado will collect increased corporate income, sales, use and severance taxes from the project. The State will also receive increased individual income taxes, highway users and other taxes from project employees and service sector employees whose jobs are generated by the project. In addition Colorado will receive 50 percent of all mineral royalty payments made to the U.S. government.

Table T is an estimation of tax revenues accruing directly to local government entities as a result of the project. These figures include only corporate property taxes, individual property taxes, individual sales taxes, and special purpose fees. They do not include any transfer of revenues which might occur between State and local governments, or Federal and local governments.

TABLE 8

ADDITIONAL LOCAL WAGE AND SALARY INCOME RESULTING FROM PROJECT OPERATION (1980 Dollars)

Year	Rifle	Meeker	Silt	Other Areas
1980	$ 7,097,000	$ 2,957,000	$ 1,182,000	$ 591,000
1981	9,161,000	3,817,000	1,527,000	763,000
1982	25,207,000	10,503,000	4,201,000	2,100,000
1983	39,972,000	16,655,000	6,662,000	3,331,000
1984	63,060,000	26,275,000	10,510,000	5,255,000
1985	94,590,000	39,412,000	15,765,000	7,882,000
1986	96,700,000	40,292,000	16,117,000	8,058,000
1987	99,188,000	41,328,000	16,531,000	8,266,000
1988	94,305,000	39,294,000	15,718,000	7,859,000
1989	91,590,000	38,163,000	15,265,000	7,632,000
1990	89,835,000	37,431,000	14,972,000	7,486,000
1991-2019	2,811,600,000	1,171,500,000	468,600,000	234,300,000
Total	$ 3,522,305,000	$ 1,467,627,000	$ 587,050,000	$ 293,523,000

TABLE T

PROJECTED DIRECT TAX REVENUES ACCRUING TO MUNICIPALITIES, COUNTIES AND SCHOOL DISTRICTS AS A RESULT OF THE PROJECT

	1980-1985	1986-1990	1991-2014	Total
Garfield County*	$ 1,855,000	$ 4,390,000	$22,033,000	$28,278,000
School District RE-2**	3,266,000	7,754,000	39,100,000	50,120,000
Rifle	2,526,000	7,088,000	35,319,000	44,933,000
Silt	638,000	1,486,000	7,455,000	9,579,000
Rio Blanco County	3,624,000	24,747,000	143,745,000	172,116,000
School District RE-1	20,748,000	122,450,000	825,707,000	968,905,000
Meeker	621,000	1,734,000	8,875,000	11,230,000

* Assumes Rifle, Silt and 50 percent of growth in other areas.
** Assumes Rifle and Silt only.

The C-B Project estimates that a total of $1,344,000,000 in corporate property taxes, $287,000,000 in severance taxes and $767,000,000 in mineral royalties will be paid to local, state and the federal government respectively, during the life of the project.

In comparing Table P with Table T some understanding can be gained of the costs of growth to local governments vs the revenues produced by the project. It should be understood when making the comparison that all local property and sales tax revenues cannot be committed solely for capital requirements, but they are the major revenue sources available for capital requirements.

School District RE-1 in Meeker, the jurisdiction which will benefit most from the corporate property taxes paid, should be in a strong position to meet capital expenditure requirements from early on. The school district will likely be able to reduce its property tax rate in later years because of the large amount of revenue generated by the project. Rio Blanco County should also receive large

tax benefits from the project, which will allow it to reach an equilibrium with its expenses in the mid-1980's. The current, relatively low tax rate imposed by Rio Blanco County, will likely be preserved.

Garfield County and School district RE-2 will not benefit directly from the industrial tax base resulting from the project, but they should receive a significant tax revenue increase as a result of population growth. Both county and school district entities should require some outside financial assistance for capital projects during the periods of construction and initial operation.

The three municipalities of Meeker, Rifle and Silt should each have difficulty meeting facility costs in future years. The municipalities will not benefit directly from any industrial tax base and sales tax revenues will increase at a slower pace than population growth. Meeker is projected to be in a long term deficit position because its current sales tax rate is only one percent. The municipalities will likely be dependent upon outside sources of financial assistance to meet necessary expenditure requirements.

The disproportionate distribution of local government tax revenues under current methods of taxation is the greatest problem in addressing population growth in the region. State and federal aid programs help to offset this inequality but other mechanisms need to be developed. The C-B Project is working with local officials to create a recreation district which will tap industrial tax base for recreation purposes in Rio Blanco County.

AESTHETIC IMPACTS

Development associated with the proposed project will consist primarily of new housing and related access roads. Most housing development will occur within existing communities and conform to established development plans. The proposed temporary man camp housing will likely be placed on the tract and integrated within the industrial complex. Visual impacts will be minimum. Some deterioration in air quality will result from urbanization.

Population densities will be increased in the communities of the region, but not to the point of overcrowding. To date population densities in Rifle and Meeker have been very low, which has resulted in a high cost, on a per capita basis, for delivery of local government services. The municipalities are now making an effort to increase densities through policies of infilling and higher density housing development, to reduce the costs of public services.

LIFESTYLE AND CULTURAL RESOURCES

Projected population growth will cause changes in the rural lifestyle of the region. People with different attitudes and preferences will migrate to the area. Agriculture and tourism will be replaced by energy resource development as the dominant local economic sector. Recreation areas will become more crowded, but a greater diversity in social, cultural and recreation experiences will be available for the population.

MEASURES AVAILABLE FOR MITIGATION OF SOCIOECONOMIC IMPACTS

There are some specific measures available to local government agencies to avoid or reduce adverse effects of rapid population growth. Some of these measures involve increased revenues either through local sources or state and federal government sources. Mitigation can also be achieved through industry initiatives, such as policies to hire and train local employees and to provide transportation and housing facilities.

ADDITIONAL TAX RESOURCES AVAILABLE FOR EXPANSION OF COMMUNITY FACILITIES AND SERVICES

As discussed in the previous section, local government entities will benefit from increased local taxes, but to varying degrees. The projected tax revenue increases displayed in Table T are based on current tax rates. Current tax rates will likely be adjusted over time, as the tax base of each entity changes. Some entities, such as the RE-1 School District and Rio Blanco County may be able to reduce taxes overal because of large increases in tax rate, while the Town of Meeker and City of Rifle may have to increase taxes in order to keep pace with the costs of growth. Some of the inequity in tax based distribution might be overcome through a cost sharing among local governments, such as a use of county revenues to finance municipal projects.

Another mechanism available for more equity distributing the tax base is the use of special service districts. For example, the C-B Project is assisting the Eastern Rio Blanco County Recreation Commission in setting up a recreation district which will incorporate the project and utilize its tax base to provide recreation facilities in Meeker.

STATE AND FEDERAL GOVERNMENT FINANCIAL ASSISTANCE PROGRAMS

The Colorado Oil Shale Trust Fund (OSTF) is a primary source of financial assistance to local governments in the project area for construction of facilities

and provision of services. The OSTF had an original sum of $75 million, which was generated by the leasehold payments made to the federal government by the C-a and the C-B Projects. The OSTF has been used extensively since 1975, and is primarily responsible for the excess capacity which now exists in local water, sewer, school, and health care facilities. Approximately $55 million is still available in the OTSF.

In addition to the OSTF, Colorado has another financial assistance program available to local governments affected by energy development. That program is the Energy Impact Assistance Program, which contains a portion of the revenues paid to the State in mineral severance taxes, and Federal mineral production royalty payments. Some $7 million each year is now available to local governments in the form of grants through the Energy Impact Assistance Program.

Other federal programs through Farmers Home Administration, HUD, EDA, EPA, DOE, and DOT are available to local governments as financial assistance for various purposes. Only the FmHA 601 Program is specifically targeted to locales experiencing energy resource development. Substantial additional Federal assistance may be made available if legislation which is now pending in the U.S. Congress is approved. S.B. 1699, which proposes a substantial assistance program of up to $2 billion, is a necessary part of any effective energy program.

PREVIOUS CORPORATE ASSISTANCE EXTENDED IN SOCIOECONOMIC AREA

The Cathedral Bluffs Project has participated in managing socioeconomic impacts from the very beginning of their involvement. Among the activities which the project has been directly involved in are the following:

IMPACT MITIGATION TASK FORCES

Formed in late 1977, the Mitigation Task Forces in Rio Blanco County and Western Garfield County remain potent mechanisms for managing socioeconomic impacts. In fact, the Western Garfield County task force was recently expanded to include the entire county. In Mesa County also, a task force has been formed with some of the same objectives.

These task forces are made up of representatives from industry and local, state and county government. Although the scope and activities of the task forces vary, their major focus is early planning and action before large scale changes occur in the area. The C-B Project, with its consultant Pace Quality Development Associates, Inc., was instrumental in implementing this process. Representatives from the C-B Project continue to attend meetings on a regular basis with the Garfield and Rio Blanco County Task Forces. A technical consultant is provided by the C-B Project to assist the task force and local government with growth management planning.

NEEDS ASSESSMENT GUIDELINES

As part of the technical assistance made available to the task forces, a workbook was prepared with guidelines for assembling needs assessments and for seeking funding. The needs assessments were prepared by local citizen volunteers working with these materials and with the project's consultants.

DEVELOPMENT GUIDES

Two major documents produced by the C-B Project were a development guide for Meeker and one for Rifle. The development guides provide a broad range of in-depth information on all aspects of the communities. This information is useful for planning and decision-making on the part of any interested group or individual concerned with the future of these two areas.

SOCIOECONOMIC MONITORING PROGRAM

In July 1978, the C-B Project initiated a monitoring program which collects and publishes information containing current work force and local socioeconomic conditions on a quarterly basis. These reports are widely distributed to public officials and other interested parties. They are particularly valuable as a corporate and public planning tool. (See Appendix A)

PLANNING ASSISTANCE

The C-B Project provides the assistance of a professional planning consultant to local public agencies and groups on an as needed basis. This professional assistance has been called upon for such projects as; developing a recreation master plan, initiating a subsidized housing project planning a hospital expansion program, financing expanded library and senior citizen programs and preparing numerous grant proposals.

TRANSPORTATION

Among the many aspects involved in competently developing a project are transportation issues and decisions that have multiple consequences. One of the major initiatives pursued by C-B management to deal with these problems was provision of a bus service for employees between Meeker and Rifle and the tract. This service was initiated early in April of 1978 and consists of six-47 passenger coaches operating 24 hours, seven days per week, from Rifle and Meeker. Pickup points and parking are provided in each town for C-B employees, contractors and contractor's employees.

The buses save fuel because of the number of passengers carried, aid in reducing road kills of livestock and wildlife, eliminate excess motor traffic on the highways (thereby lessening pollution), provide a comfortable ride and added safety for the employee. Twenty-five to thirty of these buses will be in operation as the work force expands to commercialization. The C-B Shale Oil Project also has assisted Rio Blanco County and the State Highway Department with installation of magnetic loop road counters to count vehicle traffic on Piceance Creek Road.

Other transportation matters have been investigated such as how to minimize road wildlife kills and automobile accidents, plus the possibility for using rail and pipeline services to move the shale oil.

HOUSING

An essential element related to the C-B Project is the provision of housing. In any rapid growth area housing demand is high. To deal with this problem, the C-B Project has taken several steps.

A 40-unit apartment complex has been established in Rifle and a 48-unit complex has been provided in Meeker. The units have hot water heat, two bedrooms and are furnished with refrigerator, dishwasher and stove. The grounds are completly landscaped, and have paved parking areas. A two-year lease agreement was signed with the builder to facilitate construction and permanent financing.

In addition, a mobile home park was prepared in Rifle. The park has 103 spaces expandable to 300 spaces and can accommodate single and double-wide mobile homes as well as campers and recreational vehicles. Underground utilities, laundry facilities and recreational areas are provided. This property is owned by the sponsors.

Prior to this activity, a detailed housing analysis was prepared for C-B management to assist them in their short and long-range housing plans. As a

part of the housing program, C-B personnel have worked closely with the cities of Meeker and Rifle to assure that any housing developed under their auspices or sponsorship conforms with local zoning regulations and housing standards.

Additional efforts have involved assistance by staff personnel or its consultants in obtaining elderly housing and in dealing with many of the planning issues related to housing demand and supply.

HEALTH AND HUMAN SERVICES

A constant concern of the Project is the health and safety of its employees, their families and the residents of the local communities. Considerable effort has gone into programs dealing with health and human services both for employees and the communities.

The C-B Project has provided information necessary for planning health services in both Garfield and Rio Blanco Counties. Additionally, direct planning assistance has been provided the Grand River Hospital District, Clagett Hospital and the E. Dene Moore Nursing Home. A planning guide and plan is being developed for the district.

A study was made of the social impacts experienced to date and what might be expected in the future for the oil shale area. The report was prepared in conjunction with a citizen's group from the Rifle area. Included in it are recommendations for forming a human services task force, a guide to available services in the area, an assessment of social issues in high growth communities and an explanation of what problems may be generated.

The guide, in particular, will assist new residents in identifying services available as well as locating those services. The C-B Project also has provided funds for specific programs. Included among the recipients was the Garfield County Youth Program and local television viewers who watched the presentation of "The Years Ahead", a documentary about elderly persons in Western Colorado. The presentation was co-sponsored by the C-B Project.

EMPLOYMENT

The C-B Project advertises locally through the newspapers and Job Services of Colorado Offices to fill positions at the C-B Tract. First consideration is given to local persons with requisite skills.

Personnel with the C-B Project work closely with CETA Programs and others to provide a full range of opportunities where applicable skills are available.

EDUCATION

Educational programs are conducted for both employees and community members who may someday seek employment with the project.

In addition to the training programs discussed in the following section, tuition is paid for courses leading toward a degree or providing skills relevant to the employees' job.

TRAINING PROGRAM

The C-B Project has a full time training staff and plans to expand that group as called for by employment requirements. Because of the desire to hire locally and the need to develop a large work force, training will play a critical role in the future of the project. Training will be provided in all phases of project operations from safety and basic job skills to managerial preparation. The C-B Project also has assisted Colorado Mountain College and Mesa College in the establishment of vocational courses in the area of diesel mechanics, mine electricity and other subjects relevant to the mining industry.

PROJECT SUPPORTED MITIGATION PROGRAM

A continued active role in the mitigation of socioeconomic impacts is anticipated by the project. This mitigation program will consist of two parts; the first being activities to support and strengthen the role of local governments, and the second being direct actions taken by the project.

To assist local government, Cathedral Bluffs will continue to provide current information concerning all aspects of the project. This information will include the full range of work force data and information as is now made available through the project socioeconomic monitoring reports. (See Appendix A)

Technical assistance for local government planning and development activities will also continue. Catherdral Bluffs has contributed specialized expertise when necessary to local government agencies to help them solve specific problems. This type of assistance is most valuable in rural areas where local government staffs are small and without experience in dealing with many of the problems of rapid growth. Cathedral Bluffs realizes that this type of skilled technical assistance can avoid costly mistakes or delays in public sector projects; projects which are important to the living environment of its employees.

Direct activities to be undertaken by the C-B Project to alleviate socioeconomic effects will include comprehensive programs for work recruitment, training, housing and transportation. The recruitment and training programs will be structured to hire as many local residents as possible to reduce the influx of persons to the area. Given the short supply of labor available locally, however, C-B realizes that much of the labor will have to be brought in from other areas. The recruitment program will include screening techniques to identify those persons compatible with the working environment, thus reducing the potential for turnover.

A comprehensive training program will be available to all employees which will allow local residents a better entry to employment opportunities with the

project. The training program will also enable some construction workers to make the transition to permanent employees, reducing the overall demand for labor.

The busing program which is now in operation, will be expanded as the work force expands. Busing all project employees from their community of residence to the C-B site will greatly reduce the traffic load on local roadways; reducing maintenance costs, as well as potential danger to human and animal lives.

C-B also plans to undertake a housing program, which will have the goal to providing an adequate and affordable housing unit to all project employees. The housing program will also address the housing needs of the local service work force generated by the C-B Project. Housing provided by the project, will be located in existing communities and will provide for a mix of housing types and price ranges. Housing development will conform to the comprehensive planning guidelines established locally.

Some housing will be provided on a temporary basis to alleviate the temporary demands of project construction. A worker housing camp is anticipated at or near the project site to accommodate "single-status" construction workers, thus alleviating the burden of housing these workers in existing communities.

These measures should serve to minimize many of the negative socioeconomic effects generally associated with a large industrial project located in a rural area. The C-B Project will remain committed to working closely with local government officials to mitigate socioeconomic problems as they arise.

APPENDIX

CATHEDRAL BLUFFS SHALE OIL PROJECT

SOCIOECONOMIC MONITORING REPORT

NUMBER 8

Mid-Year Report

August 1980

Prepared by

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SUMMARY

The C-B Work Force

On July 15, 1980 451 persons were employed at the Cathedral Bluffs site. Most of these workers continue to live in Rifle and Meeker full time. The percentage of new residents to the communities has increased over the last year for most local communities. The majority of the workers either live in houses or apartments, although 60 percent of those living in apartments would prefer to live in houses. The median cost of owning a home was $400, median cost renting a house was $200, median cost of renting an apartment was $265, and median cost of living in a mobile home was $185.

Ninety percent of the work force were males. The median age remains at 29 years. Less than half of the employees are married living with their families. The average family size of all married workers was 3.4 persons.

The Communities

The effects of a recessionary period is evident in the downturn of construction activity. When compared to the first half of 1979 building permits issued dropped in Meeker and Rifle in 1980. The median sales price of homes in Meeker was $58,400 and $59,500 in Rifle.

From January to June 1980 reports of criminal acts increased 113 percent in Meeker and 29 percent in Rifle when compared to 1979.

Hospital admissions in Meeker increased 55 percent in Meeker, but decreased in Rifle when compared to admissions for the same period in 1979.

School enrollment in June 1980 increased from June 1979 to June 1980 both in Meeker and Rifle about eight percent.

The unemployment rate is increasing in both Rio Blanco and Garfield counties. Although the unemployment rate in Rio Blanco county is below the state rate, Garfield's unemployment rate remains higher than the state.

Commercial bank deposits have increased in Rifle, but decreased in Meeker since the first of the year. First quarter retail sales increased four percent in Meeker and 18 percent in Rifle over retail sales for the same period in 1979. Average individual adjusted gross income increased 11 percent in Garfield County and 14 percent in Rio Blanco County.

INTRODUCTION

This is the eighth monitoring report issued by the Cathedral Bluffs Shale Oil Company. The purpose of the report is to provide local communities with selected information on the C-B project work force, as well as data on changing socioeconomic conditions.

The work force data presented in this report reflects current conditions as of July 15, 1980. The information on the work force was collected through a questionnaire completed by employees when they started work at the Cathedral Bluffs site. Completed surveys are available from 86 percent of the current work force. The surveys were coded and analyzed through a computerized data base management system.

The socioeconomic data is collected from various community agencies in Rifle and Meeker. The data is tabulated whenever possible for the first half of 1980. Comparisons are made with data from previous years.

I. THE CATHEDRAL BLUFFS WORK FORCE

As of July 15, 1980 there were 451 persons employed at the Cathedral Bluffs site. The total work force increased by 65 employees since April, with a total increase of 145 for the year. The number of employees is about at the level projected for the year. A total of 110, or 24 percent, of the employees at the site are considered permanent, while the other 76 percent hold contract or temporary jobs at the site. Figure A reflects how the actual work force compares with the manpower projections.

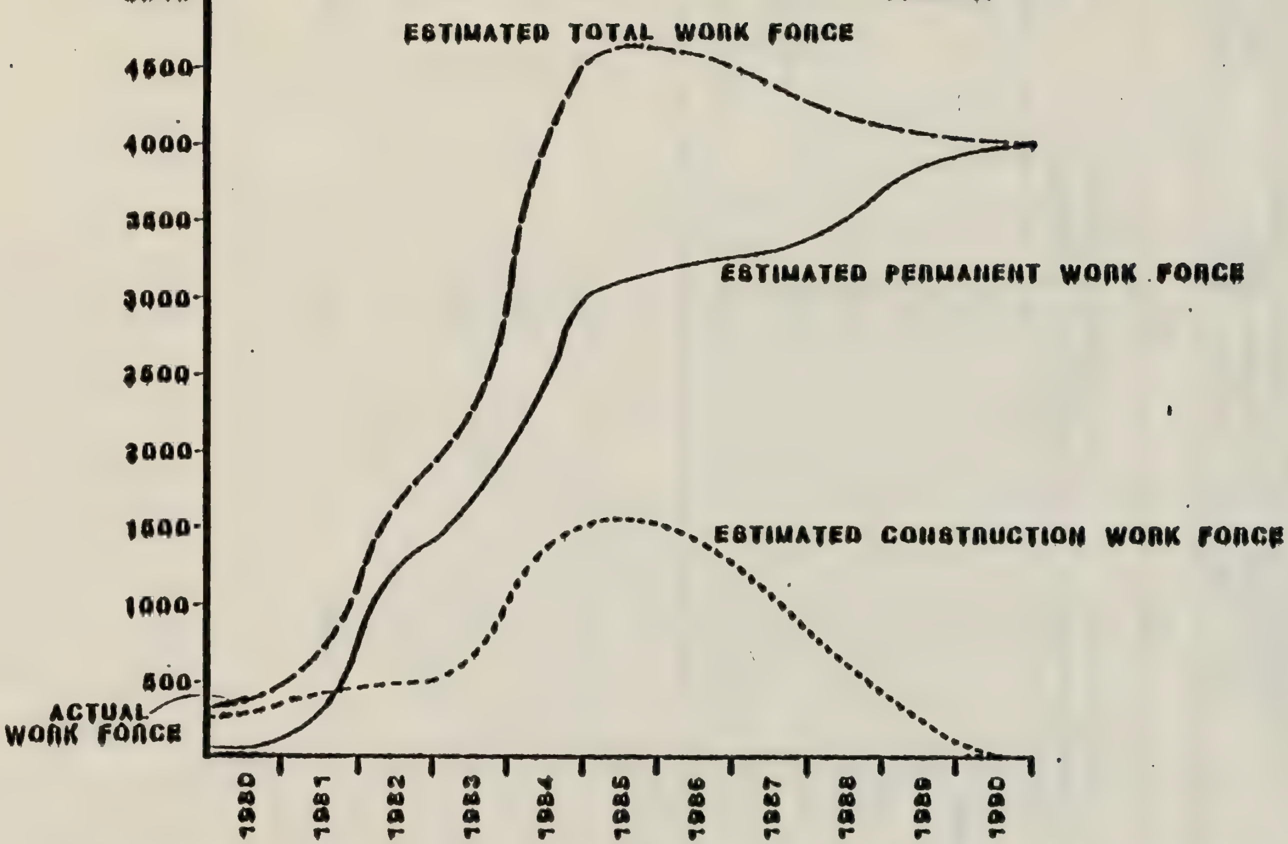
A. Housing

1. Location

Rifle remains the community where most of the workers reside. The percentage of workers residing in Meeker and Silt has remained about the same. The percentage of workers residing in Glenwood Springs has increased about 2 percent. Table I shows the place of residence of all workers surveyed as of July 1980 and compares those figures with percentages from previous reports.

At least 90 percent of the workers residing in all the communities live there full time. The percentage of workers residing full time in Rifle increased 2 percent since the last monitoring report. The percentage of workers residing full time in Meeker decreased by 3 percent since April. Table II shows the percent of those surveyed who reside in each community full time or on week days only.

FIGURE A



CATHEDRAL BLUFFS SHALE OIL PROJECT MANPOWER REQUIREMENTS

Construction Manpower	290	340	450	600	1000	1500	1500	1250	800	400	100	0
Permanent/ Operation Manpower	60	100	750	1400	2000	3000	3100	3250	3450	3700	3900	4000
Total Manpower	340	440	1200	1900	3000	4600	4600	4600	4250	4100	4000	4000
End of Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990

TABLE I

PLACE OF RESIDENCE

	Percentage of Workers Surveyed Residing There July 1979 (N = 196)	Percentage of Workers Surveyed Residing There January 1980 (N = 256)	Percentage of Workers Surveyed Residing There July 1980 (N = 389)
Rifle	58	63	61
Meeker	12	11	12
Silt	7	5	6
Grand Junction Area	7	9	7
Glenwood Springs	1	1	3
New Castle	4	2	2
Parachute	3	2	2
Rangely	1	1	1
Other West Slope	1	1	1
Piceance Creek	0	1	0
Other Colorado	0	0	1
Outside Colorado	1	1	1
Unknown	5	3	3
Total	100	100	100

TABLE II

PERCENTAGE OF WORKERS RESIDING IN COMMUNITIES
FULL TIME OR WEEK DAYS ONLY
July 1980

Community	Percent Residing in Community Full Time	Percent Residing in Community Week Days Only	
Rifle	92	8	100%
Meeker	90	10	100%
Silt	96	4	100%
Grand Junction	100	0	100%
Total Work Force	92	8	100%

2. Length of Residence

The percentage of workers who have resided in their current home less than a year has increased in most communities since the last monitoring report, although the number of short-term residents decreased in Grand Junction and Parachute. Table III shows the percentage of employees in each community according to the length of their residence.

3. Type

In most communities there was no significant change in the percentage of workers living in the various types of housing. Although there was a 10 percent increase in workers who owned houses in Grand Junction since the last monitoring report the largest percentage of the workers in Rifle and Meeker live in apartments. Table IV lists, by community, the types of housing in which the work force lives.

4. Preference

When asked to state what type of residence they preferred living in the majority of the workers indicated single family housing. Table V shows the housing preferences for those workers who expressed a housing preference. These percentages have not changed significantly during the last year.

When the response to the question on housing preference is compared to actual types of housing in which workers live, those who live in single family housing and mobile homes are least likely to desire other types of housing. Most of those living in apartments, motels, recreational vehicles, and townhouses would prefer some other type of housing. These percentages have not changed significantly since

TABLE III

LENGTH OF RESIDENCE

April and July 1980

Community	Percent of Short* Term Residents July 1979	Percent of Long** Term Residents July 1979	Percent of Short* Term Residents July 1980	Percent of Long** Term Residents July 1980
Rifle	56	44	62	38
Meeker	65	35	49	51
Silt	17	83	43	57
Grand Junction Area	50	50	29	71
Parachute	40	60	13	87
All Other Communities	56	44	33	67
Total Work Force	54	46	53	47

*Short term is defined as those residing in their current home less than one year.

**Long term is defined as those residing in their current home more than one year.

the last monitoring report. The April 1980 monitoring report incorrectly showed that 55 percent of the total work force preferred apartments. The correct figure should be 5 percent. Table VI shows this information in more detail.

TABLE IV

PERCENT OF WORK FORCE RESIDING FULL TIME
IN VARIOUS TYPES OF HOUSING
July 1980

Community	Own House	Rent House	Own Mobile Home	Rent Mobile Home	Apartment and Townhouse	RV	Motel
Rifle	18	15	12	6	36	5	8
Meeker	22	12	2	0	57	2	5
Silt	28	38	14	10	5	0	5
Parachute	43	29	14	0	14	0	0
Grand Junction	50	25	17	0	8	0	0
Total Work Force	23	18	12	7	32	3	5

5. Cost

The median cost of owning a home for the C-B workers has increased since Junuary 1980. The median monthly cost for workers who owned their own homes was $400; in Rifle the median cost was $450 and $365 in Meeker. The median cost for those who rented houses was $200 both in Rifle and Meeker. Table VII shows median cost for various types of housing in July.

TABLE V

PERCENTAGE OF WORKERS BY COMMUNITY
SHOWING HOUSING PREFERENCE
July 1980

Community	House	Mobile Home	Apartment
Rifle	74	10	16
Meeker	76	0	24
Silt	92	0	8
Parachute	100	0	0
Grand Junction	80	10	10
Total Work Force	77	8	15

TABLE VI

PERCENTAGE OF WORKERS LIVING IN VARIOUS
HOUSING TYPE AND DESIRING CHANGE
July 1980

Housing Type	Total Percentage Desiring Changes	Percentage Preferring Apartments	Percentage Preferring Houses	Percentage Preferring Mobile Homes
Apartment	65	*	60	5
House	5	4	*	1
Mobile Home	49	*	49	*
Motel	90	19	71	*
RV	78	21	43	14
Townhouse	85	8	77	*
Total	44	5	36	3

*Percentage is not shown here since numbers may indicate no preference, no response, or same type of housing preference.

TABLE VII

MEDIAN MONTHLY COST OF HOUSING TO THE C-B WORK FORCE
July 1980

Type	Median Cost Total Work Force July 1979	Median Cost Total Work Force July 1980	Median Cost Rifle July 1980	Meidan Cost Meeker July 1980
Own House	280	400	450	365
Rent House	225	200	200	200
Mobile Home	165	185	175	150
Apartment	250	265	265	275
RV	-	100	50	100
Townhouse	-	325	325	250

B. Age, Sex, Marital Status, and Family Size

1. <u>Age</u>

The median age of the work force has remained at 29 years. Median age of workers in Rifle was 28 and in Meeker it was 29.

2. <u>Sex</u>

Ninety percent of the current work force is male; 10 percent is female. This shows a 3 percent increase in the number of female employees since January 1980.

3. <u>Marital Status</u>

The marital status of the work force has continued to show that less than half of the work force are married workers living with their families. Table IX shows the percentage of workers by community according to marital status.

TABLE VIII

MEDIAN AGE BY COMMUNITY
July 1980

Community	Median Age
Rifle	28
Meeker	29
Silt	35
Grand Junction Area	30
Parachute	30
Total Work Force	29

TABLE IX

MARITAL STATUS OF WORK FORCE
July 1980

Community	Percent Married and Living With Family	Percent Married But Not Living With Family Full-Time	Percent Single
Rifle	45	20	35
Meeker	44	8	48
Silt	48	9	43
Grand Junction Area	57	4	11
Parachute	75	0	25
Total Work Force	47	16	37

4. Family Size

The average family size of all married workers in July 1980 was 3.4 persons. Table X shows the average family size of all married workers according to community.

TABLE X

AVERAGE FAMILY SIZE OF MARRIED WORKERS* BY COMMUNITY
July 1980

Community	Average Family Size
Rifle	3.3
Meeker	3.5
Silt	3.8
Grand Junction Area	3.6
Parachute	4.7
Total Work Force	3.4

*These figures include workers who do not have families living with them full time.

The 192 employees that are new to the communities (having lived there less than a year) brought with them a total of 43 preschool, 30 elementary, 5 junior high and 5 senior high children. Table XI indicates the number of children brought into local communities by workers who are short term residents.

TABLE XI

NUMBER OF SCHOOL AGE CHILDREN LIVING WITH NEW* FAMILIES
July 1980

Community	Preschool	Elementary	Junior	Senior
Rifle	34	19	2	3
Meeker	3	2	0	1
Silt	1	2	1	1
Grand Junction	2	5	0	0
Parachute	0	1	1	0
Total Work Force**	43	30	5	5

*New families are defined as those living in the local area less than one year.
**Total includes children living in communities not mentioned above.

Workers in Rifle, Meeker and Silt indicate they are planning on moving their families into the community in the near future. Employees in Rifle indicated they will move in seventeen preschool children, twenty-three elementary children, six junior high children and one senior high child. Data for other communities is presented in Table XII.

TABLE XII

NUMBER OF SCHOOL AGE CHILDREN PLANNING
TO MOVE TO LOCAL COMMUNITIES
July 1980

Community	Preschool	Elementary	Junior	Senior
Rifle	17	23	6	1
Meeker	1	5	0	1
Silt	0	2	0	0
Grand Junction	0	0	0	0
Parachute	0	0	0	0
Total Work Force	18	30	6	2

C. Recreational Activities

Fishing, hunting, skiing, and camping continue to be the most popular recreational activities of the work force. Table XIII shows the percentage of workers who indicated a preference for the most popular recreation activities.

TABLE XIII

RECREATIONAL PREFERENCE OF WORKERS SURVEYED
July 1980

Activity	Percent Responding* of Total Work Force	Precent Responding* in Meeker	Percent Responding* in Rifle
Fishing	41	35	44
Hunting	34	25	36
Skiing	14	15	16
Camping	13	19	13
Swimming	6	10	5
Golf	5	12	5
Tennis	5	8	5
Horseback Riding	2	6	2
All Sports	8	10	11

*Percentage does not total to 100 due to multiple response.

II. THE COMMUNITIES

A. Housing

1. Meeker

A substantial number of subdivision lots continue to be available in Meeker for new home construction. Six new small subdivisions have been submitted for approval during the first half of 1980. Table XIV is a listing of subdivisions under development in Meeker with the number and type of lots available in each subdivision. Sanderson Hills is still the largest subdivision under development.

Housing sales during the first half of 1980 decreased significantly according to information provided by the Rio Blanco County Assessor's office. The median price of a new single family house was $58,400, while for an older home it was $53,800. Table XV compares median housing sales figures in Meeker for the first half of 1979 and 1980.

A total of 28 building permits were issued in Meeker with a total valuation of $494,837 for the first half of 1980. Only two of these permits were for single family residences. This is a drop from the six permits issued from January to June 1979.

Available rental housing continues to remain scarce. In a given week the Meeker Herald advertises an average of one or two apartments or homes for rent. Apartments recently rented in Meeker have ranged from $300 to $525 for a 3 bedroom apartment.

TABLE XIV

MEEKER SUBDIVISIONS UNDER DEVELOPMENT

Development	General Location	Number and Type of Units
Sanderson Hills	N. Meeker	209 single family lots 140 duplex and four-plex lots Apartments, commercial, school and park land (27 units are completed and sold, 7 more units under construction and sold)
Foothills	N.W. Meeker	15 single family lots 3 four-plexes lots 1 six-plex lot
Sage Park	N.W. Meeker	15 single family lots (5 completed) 42 duplex units
Pinyon Park	N.W. Meeker	22 single family lots
White River Farms	N.E. Meeker	Preliminary plans have been submitted for this subdivision. Full scale development for this Planned Unit development would include 1,482 single-family homes, 1,048 town house 936 duplexes, 603 apartments and 819 mobile home pads. The developer would like to begin in Spring 1981 to develop mobile home park along with some apartments.
Purple Sage	N. 10 miles Strawberry Creek	3 single family lots
Mesa View II	S. of Meeker 1 mile	13 single family lots
Sage Hills	N. Meeker	111 single family lots
Warner Points I	E. of Meeker 10 miles up White River	Summer homes only on White River about 15 miles from Meeker 3 single family lots
Warner Points II	Same as Warner Points I	3 single family lots
River Bend	E. of Meeker Across from Warner Points	4 single family lots
El Escondido	N. of Meeker (Possibility of annexation)	8 single family lots

TABLE XV

HOUSING SALES IN MEEKER
1979-1980

	January-June 1979	July-December 1979	January-June 1980
Single-Family Housing (New)			
Number Sold	9	5	8
Median Sales Price	$50,200	$58,300	$58,400
Single-Family Housing (Older)			
Number Sold	37	39	27
Median Sales Price	$49,000	$50,000	$53,800
Total Single-Family Housing			
Number Sold	46	44	35
Median Sales Price	$49,100	$53,500	$58,400

2. Rifle

Currently many residential subdivisions in Rifle are proposed for development. Table XVI lists the subdivisions under development in Rifle and a description of the development status.

The Comprehensive Plan for Rifle is scheduled for completion in September.

During the first half of 1980 building permits declined 7 percent when compared to the first half of 1979. There was a significant increase in the number of building permits issued for townhouse units. Table XVII compares building permits issued from January through June for 1978, 1979 and 1980.

TABLE XVI

RIFLE SUBDIVISIONS

Development	General Location	Number and Type of Units	Status
Rifle Area			
Palomino Park	N. Rifle		
Phase I		30 Apartment Units 29 Single Family Lots	Completed Completed
Phase II		15 Single Family Lots 70 Apartment Units 20 Townhouses	14 Completed 40 Completed 4 Completed
Phase III		44 Single Family Lots	18 Completed
Phase IV		47 Single Family Lots 20 Apartment Units	0 Completed Plats withdrawn
Phase V		42 Apartment Units	Plats withdrawn
Highlands East	E. Rifle		
Phase I		37 Single Family Lots 10 Apartment Units	Completed Completed
Phase II		5 Single Family Lots 4 Apartment Units	1 Completed 0 Completed
Phase III		16 Single Family Lots	60% Completed
Phase IV		36 Single Family Lots 64 Apartment Units	30% Completed
Phase V		60 Single Family Lots	10% Completed
Phase VI		77 Single Family Lots (Cluster Homes)	Final plat approved
Pase VII		65 Single Family Lots	Sketch plan submitted
Arabian Heights	N.E. Rifle		
Phase I & II		27 Single Family Lots	20% Completed
Phase III		187 Single Family Lots	Sketch plan approved
		31 Duplexes	Sketch plan approved

Development	General Location	Number and Type of Units	Status
Rifle Area (Continued)			
Kings Crown Mobile Home Subdivision	N.W. Rifle		
Phase I		103 Mobile Home Spaces	75 percent occupied
Phase II		189 Mobile Home Spaces	Approved but not yet under construction
Shadow Ridge	W. Rifle	27 Single Family Lots 10 Duplexes 46 Townhouses 20 Condominiums	Final plat stage
Cottonwood Meadows	W. Rifle	250 - 400 Units, mixed residential	Sketch plan lapsed
Rimrock	N. Rifle		
Phase I		288 Condominiums 240 Apartments 223 Single Family Lots 100 Multi-Family (Duplexes and Four-Plexes)	Sketch plan stage
Phase II		Revising initial concepts	No action
Mesa View Estates	S.W. Rifle		
Phase I		34 Single Family Lots	90% Completed
Phase II		10 Single Family Lots	Preliminary plat stage
Knollridge P.U.D.	N.W. Rifle	34 Single Family Lots 52 Duplexes 100 Townhouses 168 Multi-Family Apartments	Preliminary plat approved
North Meadows	N. Rifle	250 Multi-Family	Sketch plan approved
Rifle Heights	E. Rifle	100 Single Family	Sketch plan lapsed
Mahogany Additon	S. Rifle	48 Multi-Family Units	0 Completed
Trapper Hollow P.U.D.	W. Rifle	28 Condominium Units	0 Completed

Development	General Location	Number and Type of Units	Status
Rifle Area (Continued)			
Barnett P.U.D.	W. Rifle	20 Condominium Units	Final Plat approved
Carmack Mobile Home Subdivision	N. Rifle	300 Mobile Home Lots 40 Multi-Family Units	Sketch plat approved
Creek Meadows	N. Rifle	152 Multi-Family Units	Preliminary plat approved
Fairview Addition		20 Condominiums	Sketch plan approved
Jackson Heights (Senior Citizen and subsidized housing)	W. Rifle	8 Single Family Lots 25 Condominiums 16 Cluster Houses	Sketch plan approved

TABLE XVII

BUILDING PERMITS ISSUED IN RIFLE

	Jan-Jun 1978	Jul-Dec 1978	Jan-Jun 1977	Jul-Dec 1979	Jan-Jun 1980
Single Family Homes	34	36	54	44	50
Town Houses	4	0	0	9	12
Seven-plex Units	0	0	0	0	1
Four-plex Units	4	9	1	5	2
Duplex Units	9	3	6	6	1
Commercial Buildings	*	*	*	*	4
Mobile Home Permits	*	*	*	*	68
Total Permits	*	*	*	*	188
Valuation	*	*	*	*	$5,493,615

*Data not available in previous reports

On the average 3-4 rental units were advertised each week in the Rifle Telegram. Rental rates for two and three bedroom houses ranged between $300 and $375. Apartments rented for $250-$375 per month. New town houses rented for $400-$440 per month.

During the first 6 months of 1980 44 homes were sold. This is a 69 percent increase over the number of homes sold during the same period of time last year. Twenty-nine of these were older homes, fifteen were new homes. The median sales price of all the homes sold was $59,500. The median sales price for new homes sold was

$69,900 and for older homes $55,000. The volume of home sales and the median sales price are shown in Table XVIII. These figures demonstrated a continued rapid increase in the price of housing in Rifle, especially newly constructed housing.

TABLE XVIII

HOUSING SALES IN RIFLE
January-June 1979, 1980

	January-June 1979	January-June 1980
Single Family Housing (New)		
Number Sold	15	15
Median Sales Price	$62,500	$69,900
Single-Family Housing (Older)		
Number Sold	11	29
Median Sales Price	$50,000	$55,000
Total Single Family Housing		
Number Sold	26	44
Median Sales Price	$58,000	$59,500

B. Law Enforcement and Fire Protection

1. <u>Meeker</u>

Through most of 1980 the Meeker Police Department has been shorthanded with only four officers for four months. Crime reports this year have increased 113 percent over reports for the first half of 1979. Fraud and distrubance show the greatest increase in reports. The category of disturbance includes reports of disorderly conduct littering, harrassment, and prowlers. Table XIX lists selected crimes reported in Meeker for the first half of 1979 and 1980.

TABLE XIX

MEEKER LAW ENFORCEMENT DATA
January-June 1979-1980

Selected Crimes Reported[1]	January-June 1979	January-June 1980	1979-1980[3] Percent Increase
Assault	6	4	(-33)
Burglary	9	7	(-22)
Theft	46	46	0
Vandalism	33	47	42
Sex Offenses	0	0	0
Narcotics/Drugs	2	4	100
DUI/DWI[2]	8	6	(-25)
Disturbance	18	73	305
Fraud	5	29	480
Runaway	4	6	50
Total Reports	155	330	113
Number of Officers	5	4 - Jan-April 5 - May-June	-

1 All crimes reported are not included in this report.
2 Driving under the influence, driving while intoxicated.
3 Calculated using a six month base.

Source: Meeker Police Department

Meeker volunteer fire department responded to 14 fire calls and 52 ambulance calls during the first half of 1980. This compares to 21 fire calls from January to June 1980. Currently there are 30 volunteer fireman, of which seven are ambulance drivers (EMT's). Meeker recently received a 250 GPM pumper truck and have received bids for a 1,000 GPM pumper truck for consideration.

2. Rifle

The number of crimes reported in Rifle for the first half of 1980 were up 29 percent over 1979 crimes reported. Crimes of theft, narcotics/drugs, vandalism increased the most. A breakdown of crimes reported in Rifle for January through June 1979 and 1980 are included in Table XX.

TABLE XX

RIFLE LAW ENFORCEMENT DATA
January - June 1979-1980

Selected Crimes Reported[1]	January-June 1979	January-June 1980	1979-1980[3] Percent Increase
Theft	97	117	21
Assault	7	5	(-28)
Narcotics/Drugs	1	4	300
DUI/DWI[2]	17	41	24
Fraud/Forgery	19	14	(-26)
Disorderly Conduct	37	35	5
Criminal Trespass	12	-	-
Vandalism	20	29	45
Family Disturbance	0	2	200
Child Abuse/Neglect	1	-	-
Runaways	8	7	13
Curfew Violation	3	-	-
Total Reports	352	455	29

[1] All crimes reported are not included in this report.

[2] Driving under the influence, driving while intoxicated.

[3] Calculated using a six month base.

Source: Rifle Police Department

C. Hospitals and Health Care

1. Meeker

Between January and June 1980 total admissions to the Pioneer Memorial Hospital increased 55 percent over the admissions for the same time period in 1979. Emergency room visits increased 30 percent. Table XXI compares hospital data for the first half of 1979 and 1980.

Pioneer Hospital recently began an expansion program to increase the capacity of the emergency room and laboratory facilities. Completion of the project is scheduled for January 1980. Meeker still has three full-time physicians in practice.

2. Rifle

Clagett Memorial Hospital had a decrease in total admissions during the first half of 1980 when compared to 1979. There was a slight increase in the number of emergency room visits (Table XXII).

Currently Rifle has seven active physicians with the addition of an orthopedic surgeon.

D. School Data

1. Meeker

Total school enrollment increased about eight percent from June 1979 to June 1980. The junior high grades show the largest increase in

TABLE XXI

HOSPITAL DATA FOR RIFLE AND MEEKER

	CLAGETT MEMORIAL HOSPITAL		PIONEER MEMORIAL HOSPITAL	
	January-June 1979	January-June 1980	January-June 1979	January-June 1980
Total Admissions	522	494	184	286
Total Emergency Room Visits	1,366	1,370	526	683
Average Daily Census	11.5	10.6	4.8	6.9
Average Occupancy	35.9	33.2	28.5%	40.8%
Total Newborn	41	36	28	27

enrollment (see Table XXII). Currently a core facility is being added to the senior high, with an auxiliary gymnasium, locker space and showers.

2. Rifle

Total enrollment in the Garfield County School District RE-2 increased about eight percent from June 1979 to June 1980. As the new school year starts in September 1980 there will be 107 teachers, twenty of these teachers are new to the district. Table XXIII presents enrollment figures over the past year.

TABLE XXII

MEEKER SCHOOL DISTRICT RE-1 ENROLLMENT

Enrollment	Capacity	June 1979	January 1980	June 1980
Rock School (grades 1-8)	40	25	26	26
Kindergarten		52	61	64
Grades 1-4	350	261	282	276
Grades 5-6	150	124	125	130
Grades 7-8	250	108	121	130
Senior High	450	283	243	238
Total	1,240	803	858	864
Staff Certified (FTE)		46.35	46.86	46.86

TABLE XXIII

GARFIELD COUNTY SCHOOL DISTRICT RE-2 ENROLLMENT

	Capacity	June 1979	January 1980	June 1980
Silt (K-6)	150	*	*	201
New Castle (K-8)	275	*	*	326
Esma Lewis (K-6)	450		*	608
Total Elementary	875	922	1,018	**
Rifle Junior High (7-8)	300			209
Senior High (9-12)	400			491
Total Secondary	700	802	809	**
Total Enrollment	1,575	1,704	1,827	1,835

*Enrollment not broken down by schools in previous reports.
**Total enrollment not given since New Castle school includes seventh and eighth grade.

E. Labor Force

In spite of increased employment opportunities due to energy development recessionary forces seem to have affected county employment. Data on employment and unemployment are only available at the county level. In both Rio Blanco County and Garfield County the unemployment rate is increasing when compared to last year's statistics. Table XXIV compares current labor forces statistics with previous years and months. The unemployment rate in Rio Blanco County is below the state's, while the unemployment rate in Garfield County is greater than the state rate.

TABLE XXIV

EMPLOYMENT, UNEMPLOYMENT AND LABOR FORCE ESTIMATES

		Rio Blanco County		
Total Labor Force	3,095	3,010	3,211	3,352
Total Employment	3,047	2,961	3,137	3,244
Total Unemployment	48	49	74	108
Unemployment Rate	1.6	1.6	2.3	3.2
		Garfield County		
Total Labor Force	11,661	11,501	12,102	12,266
Total Employment	11,152	11,077	11,525	11,732
Total Unemployment	509	424	577	534
Unemployment Rate	4.4	3.7	4.8	4.4
State Unemployment Rate	3.2	3.2	3.6	3.6

Source: Colorado Department of Labor and Employment

F. Economic Indicators

1. Commercial Banks

Commercial bank deposits have increased in Rifle, but decreased in Meeker since the first of the year. Table XXV shows deposits and loans.

A new industrial bank began operating in Rifle in February. Two business groups have submitted applications to the Colorado Banking Board to open a new commercial bank in Rifle. A joint hearing is scheduled for November to determine if the charter will be granted.

TABLE XXV

COMMERCIAL BANK DEPOSITS AND LOANS
1997 - 1980

	MEEKER	RIFLE
Total Deposits		
June 1980	$16,983,438	$21,759,000
December 1979	17,496,199	21,513,000
June 1979	16,352,000	17,056,000
December 1978	15,871,000	17,056,000
December 1977	14,512,000	14,142,000
Total Loans		
June 1980	$13,414,706	$15,542,000
December 1979	12,690,006	14,184,000
June 1979	13,040,000	13,230,000
December 1978	12,071,000	11,697,000
December 1977	9,746,000	9,201,000

Source: First National Bank of Rifle
First National Bank of Meeker

2. Retail Sales - Meeker

First quarter retail sales figures for 1980 show that Meeker has had an increase of 4 percent over retail sales for the same period in 1979. Retail sales from finance, real estate and insurance establishments increased the most dramatically. Eating and drinking business also increased substantially. Many other types of businesses showed decreases in retail sales (see Table XXVI).

3. Retail Sales - Rifle

First quarter retail sales for 1980 in Rifle for all industries show an 18 percent increase over first quarter sales in 1979. Although the categories of buiding material, finance, insurance and real estate, and contract construction all showed a decrease in retail sales. These decreases can be attributed to U.S. recessionary conditions and slow down of home building. Table XXVII presents retail sales figures for 1979 and first quarter sales 1979 and 1980.

4. Personal Income

The Bureau of Economic Analysis publishes statistics indicating per capita personal income by county. Personal income is the income of residents of an area from all sources. It is measured after deduction of personal contributions to old age, retirement and other social insurance programs, but before deduction of income and other personal taxes. The latest figures available are for 1978. Per capita income has been steadily increasing in Garfield and Rio Blanco counties. Table XXVIII shows per capita income for the five years for Garfield and Rio Blanco counties.

TABLE XXVI

FIRST QUARTER RETAIL SALES 1979-1980

MEEKER

Type of Business	1979 Yearly Total*	1st Quarter 1979*	1st Quarter 1980*	Percent Change from Quarter 1979-1980
Building Materials	1,401	354	185	(-48)
General Merchandise	754	149	179	20
Food Stores	3,191	584	744	27
Automotive	3,058	851	688	(-19)
Apparel and Accessory	72	17	15	(-12)
Furniture	464	124	76	(-39)
Eating and Drinking	668	76	158	108
Miscellaneous	1,974	410	284	(-30)
Total Retail Trade	11,582	2,565	2,329	(- 9)
Fin., Ins. & Real Estate	20	1	5	400
Hotels and Lodging	179	9	39	333
Other Services	718	153	168	10
Total Services	917	163	213	31
Wholesale Trade	1,212	7	195	
Agriculture	4	2	3	50
Mining	545	85	195	129
Contract Construction	476	80	83	4
Manufacturing	292	80	69	(-14)
Trans., Comm. & Pub. Util.	1,072	280	309	10
Government	--	--	--	--
Nonclassifiable	--	--	--	--
Total Other Industries	3,062	533	855	60
Total All Industries**	16,101	3,262	3,398	4
% of County	31%	28%	23%	

*Figures in Thousands
**Totals may not add up due to rounding

Source: Colorado Department of Revenue, Division of Research and Statistics

TABLE XXVII

FIRST QUARTER RETAIL SALES 1979-1980

RIFLE

Type of Business	1979 Yearly Total*	1st Quarter 1979*	1st Quarter 1980*	Percent Change from Quarter 1979-1980
Building Material	1,533	675	204	(-70)
General Merchandise	439	79	87	10
Food Stores	8,205	1,764	1,972	12
Automotive	5,800	1,294	1,698	31
Apparel and Accessory	427	69	85	23
Furniture	606	131	155	18
Eating and Drinking	1,811	398	450	13
Miscellaneous	4,091	1,046	835	(-20)
Total Retail Trade	22,912	5,458	5,486	1
Fin., Ins. & Real Estate	41	11	8	(-27)
Hotels and Lodging	401	33	88	166
Other Services	3,705	930	697	(-25)
Total Services	4,147	974	793	(-18)
Wholesale Trade	7,580	801	2,185	172
Agriculture	--	--	--	--
Mining	--	--	--	--
Contract Construction	415	100	82	(-18)
Manufacturing	350	7	41	485
Trans., Comm. & Pub. Util.	1,746	464	623	34
Government	--	--	--	--
Nonclassifiable	--	--	--	--
Total Other Industries	10,091	1,372	2,931	114
Total All Industries**	37,150	7,804	9,210	18
% of County	17%	15%	17%	

*Figures in Thousands
**Totals may not add up due to rounding

Source: Colorado Department of Revenue, Division of Research and Statistics

TABLE XXVIII

PER CAPITA PERSONAL INCOME

COUNTY	1974	1975	1976	1977	1978
Garfield	4,835	5,527	6,236	6,665	7,574
Rio Blanco	4,507	4,565	5,711	7,298	8,940

Source: Bureau of Economic Analysis

The Colorado Department of Revenue also publishes information on personal income from income tax returns. These figures are slightly higher than those produced by the Bureau of Economic Analysis (see Table XXIX), because of a different method of determining income. The Department of Revenue figures are determined by dividing the total income from income tax returns by the total number of returns. Whereas the BEA figures divide total income by population.

TABLE XXIX

AVERAGE INDIVIDUAL ADJUSTED GROSS INCOME
Fiscal Year Ended June 30, 1977, 78, 79

COUNTY	1977	1978	1979	Percent Increase 1978-1979
Garfield	$11,031.50	$12,194.97	$13,509.08	11%
Rio Blanco	11,062.66	12,249.62	13,915.89	14%

Source: Colorado Department of Revenue Annual Report

10.0

APPENDIX 10.0

SECONDARY EMISSION FACTORS

TABLE OF CONTENTS

APPENDIX 10-A
EMISSION FACTORS FOR VEHICLES
(grams per mile)

Emission	Automobile (Gas)	Light Truck (Gas)	Heavy Diesel
Carbon Monoxide	8.44	19.45	12.12
Sulfur Dioxide	0.13	0.18	2.8
Particulates	0.25	0.25	1.3
Nitrogen Oxides	1.94	1.94	7.20
Hydrocarbons	1.03	1.76	1.46

APPENDIX 10-B
EMISSION FACTORS FOR NATURAL GAS COMBUSTION
(pounds per million standard cubic feet)

Emission	Emission Factor
Carbon Monoxide	20
Sulfur Dioxide	0.6
Particulates	15
Nitrogen Oxides	80
Hydrocarbons	8

APPENDIX 10-C
EMISSION FACTORS FOR DIESEL LOCOMOTIVES
(pounds per thousand gallons of fuel oil)

Emission	Emission Factor
Carbon Monoxide	130
Sulfur Dioxide	57
Particulates	25
Nitrogen Oxides	370
Hydrocarbons	94

11.0

APPENDIX 11.0

Supporting Air Diffusion Modeling Tables

These tables support Chapter VI.

Air Diffusion Modeling Results

and are described therein

(Tables 11.1 thru 11.12)

TABLES IN APPENDICES

TABLE 11.1

As Modeled Emission Sources

Model Source No.	Source Identification	Source Type	Applicable Year	Pollutant SO_2	TSP	NOX	CO
PRIMARY	SOURCE						
1'a-1'c	Conveyors #1-1A Combined	Point	All		X		
3'	Combined Transfer Pt. for 1, 1A, 2, 2A				X		
5a-5c	Conveyor #2				X		
6a-6c	Conveyor #2A				X		
7'	Stacking Tower Load-Ins (Sources 7, 8)				X		
9'	" " " " " 9, 10)				X		
13	Conveyor #14 Transfer Point				X		
14	Transfer-Stacking Tower to Conveyor #3A				X		
15	" " " " " #3				X		
17'a-17'b	Conveyors #3 & 3A (Combined)				X		
19	Secondary & Tertiary Crushing				X		
20'	Conveyors #4 & 4A (Combined) (20 & 21)				X		
22	Conveyor #6				X		
23	Conveyor Transfer Area				X		
24	Conveyor #15 Transfer Pt.				X		
26	30k Ton Storage Silo Load-in				X		
27'	30k Ton Storage Silo Load-out (27 & 28)				X		
29	Spent Shale Handling and Disposal Pt.				X		
43	Mine Exhaust Shaft #1			X	X	X	X
44	Mine Exhaust Shaft #2			X	X	X	X
52	FGD Stack #1			X	X	X	X
53	" " #2			X	X	X	X
54	" " #3			X	X	X	X
55	" " #4			X	X	X	X
56	" " #5			X	X	X	X
58	Eleven Temp. Power Generators			X	X	X	X
59	Cement Batch Plant			X	X	X	X
60	Cement Batch Plant Boiler			X	X	X	X
61	Lurgi Flue Gas Stacks U# 1 & 5			X	X	X	X
62	" " " " U# 2, 3, 6, 7			X	X	X	X
63	" " " " U# 4 & 8			X	X	X	X
11	Raw Shale Dump to Conv. #14 yr 10		10		X		
11	" " " " " " yr 15		15		X		
11	" " " " " " yr 25		25				
12a-12b	Conveyor #14 yr 10		10				
12a-12c	" " yr 15		15		X		
12a-12f	" " yr 25		25		X		
16a-16f	Conveyor #15 yr 10		10		X		
16a-16d	" " yr 15		15		X		
16a-16d	" " yr 25		25		X		
25	Conveyor #15 Trans. Pt. 10 yr		10		X		
25	" " " " 15 yr		15		X		
25	" " " " 25 yr		25		X		
30'	Spent Shale Disp. Pt. 10 yr		10		X		
30'	" " " " 15 yr		15		X		
30'	" " " " 25 yr		25		X		
32'a-32'j	Spent Shale Disp. to & Over Stpile (32 & 41) 10 yr		10		X		
32'a-32'f	" " " " " " " " 15 yr		15		X		
32'a-32'h	" " " " " " " " 25 yr		24		X		
33a-33g	Spent Shale Pile 10 yr	Area	10		X		
33a-33f	" " " 15 yr		15		X		
33a-33h	" " " 25 yr		25		X		

TABLE 11.1
As Modeled Emission Sources

Model Source No.	Source Identification	Source Type	Applicable Year	Pollutant SO_2	TSP	NOX	CO
34a-34e	Raw Shale Pile 10 yr	Area	10		X		
34a-34k	" " " 15 yr		15		X		
34a-34h	" " " 25 yr		25		X		
35	Conveyor #16 Transfer Pt. 25 yr	Point	25		X		
36	" " " " 25 yr		25		X		
37a-37f	" " 25 yr		25		X		
38a-38k	Topsoil Removal & Spent Shale Pile 10 yr	Area	10		X		
38a-38f	" " " " " 15 yr		15		X		
38a-38h	" " " " " 25 yr		25		X		
42a-42k	Topsoil Dumping & Scraping & Spent Shale Pile 10yr		10		X		
42a-42k	" " " " " " 15yr		15		X		
42a-42m	" " " " " " 25yr		25		X		
45a-45c	Emiss. To & Over Raw Shale Pile 10 yr	Point	10		X		
45a-45c	" " " " " " 15 yr		15		X		
45a-45b	" " " " " " 25 yr		25		X		
47a-47e	Topsoil Dumping, Scraping, Shaping & Raw Shale Pile 10yr		10		X		
47a-47f	" " " " " " " 15yr		15		X		
47a-47b	" " " " " " " 25yr		25		X		
49	Veh. Emiss. Over Raw Shale Pile 10 yr		10		X		
49	" " " " " " 15 yr		15		X		
49a-49b	" " " " " " 25 yr		25		X		
50a-50d	Topsoil Removal & Raw Shale Area 10 yr		10		X		
50a-50d	" " " " " 15 yr		15		X		
50a-50c	" " " " " 25 yr		25		X		
SECONDARY SOURCE							
64a-64w	Vehicle Emission Piceance Creek Road	Point	All	X	X	X	X
65	Rifle, Colorado			X	X	X	X
66a-66s	" " Rifle to Rio Blanco Store			X	X	X	X
67a-67w	" " Rio Blanco Store to Meeker			X	X	X	X
68	Meeker, Colorado			X	X	X	X

Date

TABL .2

Run Group

SO_2 Emissions Input for Air Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	SO_2 Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (2000 g) 1000 g	Y Coord. (2000 g) 1000 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Mine Exhaust Shaft 1	43	(1.008)	(30.00)	(294.0)	(19.10)		(16.23)	(459.90) 459.80	(60.40) 60.70	6920	0		Input Plume rise from Eqs. (13)-(15) Table 4
Mine Exhaust Shaft 2	44	(1.008)	(30.00)	(294.0)	(19.10)		(16.23)	(460.50) 461.00	(60.40) 60.70	6720			" " "
FGD Stack #1	52	(44.00)	(34.00)	(346.0)	(36.60)	(4.71)	(637)	(460.10) 460.20	(60.30) 60.70	6850			
FGD Stack #2	53	(44.00)	(34.00)	(346.0)	(36.60)		(637)	(460.10) 460.20	(60.30) 60.60	6850			
FGD Stack #3	54	(44.00)	(34.00)	(346.0)	(36.60)		(637)	(460.20) 460.30	(60.30) 60.60	6850			
FGD Stack #4	55	(44.00)	(34.00)	(346.0)	(36.60)		(637)	(460.20) 460.40	(60.30) 60.60	6850			
FGD Stack #5	56	(44.00)	(34.00)	(346.0)	(36.60)		(637)	(460.20) 460.40	(60.30) 60.60	6850			
11 Temp. Power Gen. 5	58	(.010)	(6.10)	(845.0)	(200.00)	(0.85)	(113)	(459.50) 458.90	(60.80) 61.60	6828			
Cmt Batch Plant Boiler	60	(0.260)	(5.50)	(589.0)	(15.70)	(0.51)	(3.21)	(459.50) 459.10	(60.70) 61.30	6828			
U#1 & 5 Lurgi Flue Gas Stacks	61	(3.87)	(30.00)	(433.0)	(36.60)		(189.7)	(460.00) 460.00	(60.20) 60.40	6890			
U#2, 3, 6, 7 Lurgi Flue Gas Stacks	62	(5.80)	(30.00)	(433.0)	(36.60)		(284.5)	(460.00) 460.10	(60.20) 60.40	6895			
U#4 & 8 Lurgi Flue Gas Stacks	63	(3.87)	(30.00)	(433.0)	(36.60)		(189.7)	(460.10) 460.20	(60.20) 60.30	6900			

Date _

TABLE 11.3

TSP Emissions Input for Air Quality Modeling of Tract C-b

Run Group

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr* 24 hr/Ann	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Conveyors #1-1A Combined	1'a	(.074)	(2)	(288)	(1)	(1)	Calculated	(456.00) 444.00	(66.30) 85.40	6971	0	(5)	
" " "	1'b							(456.50) 446.10	(66.20) 84.70	6999			
" " "	1'c							(457.10) 448.50	(66.00) 83.90	7028			
Conveyor #1, 1A, 2, 2A Combined Transfer Pt.	3'	(0.257)			(15)	(0.46)		(457.60) 450.40	(65.90) 83.40	6945			
Conveyor #2	5a	(0.04)			(1)	(1)		(457.70) 450.90	(65.10) 80.40	6932			
" "	5b							(457.80) 451.20	(64.40) 77.60	6932			
" "	5c							(457.90) 451.70	(63.70) 74.80	6932			
Conveyor #2A	6a	(0.05)						(457.80) 451.20	(65.20) 80.70	6932			
" "	6b							(458.00) 451.80	(64.50) 78.00	6932			
" "	6c							(458.20) 452.70	(63.80) 75.30	6932			
Stacking Tower Load-ins (7 & 8)	7'	(0.135)	(15)		(15)	(0.71)		(458.30) 453.30	(63.20) 72.80	6957			
Stacking Tower Load-ins (9 & 10)	9'	(0.115)	(15)		(15)	(0.71)		(458.00) 452.10	(63.00) 72.20	6957			

* Differ because of duty cycle

Date ________

TABLE 11.3 (Cont'd)

TSP Emissions Input for Air Quality Modeling of Tract C-b

Run Group ________ ________

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr 24 hr/Ann	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200) Grid 50 Grid	Y Coord. (200) Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Conveyor #14 Transfer Pt.	13	(0.023)	(2)	(298)	(15)	(1)		(457.60) 450.50	(65.90) 83.60	6945	0	(5)	
Transfer Stacking Tower to Conveyor #3A	14	(0.17)			(1)			(458.30) 453.30	(63.20) 72.80	6836			
Transfer Stacking Tower to Conveyor #3	15	(0.17)						(458.00) 452.10	(63.00) 72.20	6836			
Conveyors #3 & 3A (Combined)	17'a	(0.122)						(458.50) 454.10	(63.00) 71.80	6930			
" " "	17'b	(0.122)						(459.00) 455.90	(62.80) 71.20	6883			
Secondary & Tertiary Crushing	19	(5.675) (5.43)	(25)		(15)	(2.67)		(459.30) 457.30	(62.90) 71.70	7000			
Conveyors #4 & #4A (Combined)	20'	(0.810)	(2)		(1)	(1)		(459.50) 457.80	(63.00) 72.10	6922			
Conveyor #6	22	(0.811)	(2)		(1)	(1)		(459.50) 457.80	(63.00) 72.10	6947			
Conveyor Transfer Pt.	23	(0.64) (0.612)	(23)		(15)	(1)		(459.50) 458.10	(63.30) 73.40	6980			
30,000 ton storage silo Load-In	26	(0.094)	(20)		(6.1)	(1.00)		(459.90) 459.50	(61.80) 67.20	7060			
Spent Shale Handling & Disposal Pt.	29	(3.045) (2.91)	(10)		(15)	(1.1)		(461.40) 465.60	(61.10) 64.50	7016			
Mine Exhaust Shaft #1	43	(4.53) (4.34)	(30)	(294)	(19.1)	(10.4)	(1623)	(459.00) 456.20	(63.60) 74.50	6920			Jet Plume Rise Input from Eqs.(13)-(15) Table 4

Date _

TABLE 1' (Cont'd)

TSP Emissions Input for Air Quality Modeling of Tract C-b

Run Group

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr 24 hr/Ann	Stack Ht. (m) ft.	Exit Temp. (^{o}K) ^{o}F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200) Grid 50 Grid	Y Coord. (200) Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Mine Exhaust Shaft #2	44	4.53 / (4.34)	(30)	(294)	(19.1)	(10.4)	(1623)	(464.80) 479.20	(63.50) 74.00	6720	0		Jet Plume Rise input from Eqs. (13)-(15) Table 4
FGD Stack #1	52	(1.69)	(34)	(346)	(36.6)	(4.71)	(637)	(460.90) 463.50	(63.30) 73.30	6850			
" " #2	53							(461.20) 464.80	(63.20) 72.90	6850			
" " #3	54							(461.50) 466.10	(63.10) 72.40	6850			
" " #4	55							(461.90) 467.40	(63.00) 72.00	6850			
" " #5	56							(462.20) 468.70	(62.90) 71.60	6850			
11 Temp. Power Gens	58	0.00	(6.1)	(845)	(200)	(0.85)	(113)	(454.50) 438.10	(67.90) 91.70	6828			
Cement Batch Plant	59	(0.05)	5.50	(288)		(0.34)	(1.24)	(455.40) 441.70	(66.60) 86.20	6828			
Cement Batch Plant Boiler	60	(0.06) / (0.03)	(5.5)	(589)		(0.51)	(3.21)	(455.40) 441.70	(66.60) 86.20	6828			
30,000 Ton Storage Silo Loadout (27 & 28)	27'	(0.012)	(20.0)	(288)	(6.10)	(1.00)		(459.10) 456.20	(61.90) 67.40	6908		(5)	
Conveyor #15a Transfer Pt.	24	(0.829)	(10)	(288)	(15)	(1)		(460.80) 463.20	(62.40) 69.40	6820			
Conveyor #16a Transfer Pt. Yr 25	35	(0.829)	(10)	(288)	(15)	(1)		(466.60) 486.50	(59.40) 57.70	6900			

Date ______

TABLE 11 'Cont'd)

TSP Emissions Input for Air Quality Modeling of Tract C-b

Run Group ______

SOURCE I. D.	Source No.	TSP Emission Rate	Stack Ht.	Exit Temp.	Exit Speed	Stack Diameter	Actual Vol. Flow	X Coord.	Y Coord.	Source Elev.	Source Width	Input Plume Rise	REMARKS
		(gm/sec) lb/hr 24 hr/Ann	(m) ft.	(^oK) ^oF	(m/sec) ft/sec	(m) ft.	(m^3/sec) WACFM	(200) Grid 50 Grid	(200) Grid 50 Grid	ft.	(m) ft.	(m) ft.	
Conveyor #16 (B) Transfer Pt. Yr 25	36	(0.829)	(10)	(288)	(15)	(1)		(467.60) 490.40	(66.10) 84.40	7140	0	(5)	
Lurgi Flue Gas Stacks U=1 & 5	61	(13.2)	(30)	(433)	(36.6)		189.7	(459.90) 459.60	(62.00) 67.90	6890			
Lurgi Flue Gas Stacks U=2, 3, 6, 7	62	(19.8)					284.5	(460.40) 461.70	(61.80) 67.20	6895			
Lurgi Flue Gas Stacks U=4 & 8	63	(13.2)					189.7	(460.80) 463.40	(61.60) 66.60	6900			
Raw Shale Dump to Conv #14 Yr 10	11	(0.066)	(30)	(288)		(15)		(459.90) 459.60	(67.60) 90.50	6740			
" " " " " " Yr 15	11	(0.066)						(460.40 461.40	(67.90) 91.70	6725			
" " " " " " Yr 25	11	(0.066)						(463.40) 473.70	(69.50) 98.00	6710			
Conveyor #14 (A) Yr 10	12a	(0.085)	(2)		(1)	(1)		(458.30) 453.10	(66.50) 86.00	6840			
" " (B) " "	12b							(459.10) 456.30	(67.10) 88.20	6800			
" " (A) Yr 15	12a	(0.057)						(458.20) 452.90	(66.40) 85.50	6800			
" " (B) " "	12b							(458.90) 455.60	(67.00) 87.80	6790			
" " (C) " "	12c							(459.60) 458.50	(67.40) 89.60	6710			

Date ______

TABLE ? (Cont'd)

TSP Emissions Input for Air Quality Modeling of Tract C-b

Run Group ______

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr 24 hr/Ann	Stack Ht. (m) ft.	Exit Temp. (°K) °F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200)Grid 50 Grid	Y Coord. (200)Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Conveyor #14 (A) Yr 25	12a	(0.028)	(2)	(288)	(1)	(1)		(458.30) 453.10	(66.40) 85.70	6800	0	(5)	
" " (B) " "	12b							(459.00) 455.90	(66.90) 87.70	6760			
" " (C) " "	12c							(459.70) 458.70	(67.40) 89.70	6750			
" " (D) " "	12d							(460.40) 461.40	(68.00) 91.90	6740			
" " (E) " "	12e							(461.10) 464.30	(68.50) 94.00	6730			
" " (F) " "	12f							(461.80) 467.00	(69.00) 96.00	6700			
Conveyor #15 (A) Yr 10	16a	(0.009)						(462.30) 469.40	(60.00) 60.00	6860			
" " (B) " "	16b							(462.30) 469.40	(59.10) 56.50	6910			
" " (C) " "	16c							(462.40) 469.40	(58.30) 53.30	6960			
" " (D) " "	16d							(462.40) 469.50	(57.50) 50.00	7000			
" " (E) " "	16e							(462.40) 469.50	(56.60) 46.50	7050			
" " (F) " "	16f							(462.40) 469.50	(55.70) 42.90	7090			

TPS Emissions Input for Ai ality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr 24 Hr/Ann	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200)Grid 50 Grid	Y Coord. (200)Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Conveyor #15 (A) Yr 15	16 a	(0.014)	(2)	(288)	(1)	(1)		(463.20) 472.90	(60.50) 62.00	6884	0	(5)	
" " (B) " "	16 b							(464.10) 476.30	(60.20) 60.90	6948			
" " (C) " "	16 c							(465.00) 479.80	(59.90) 59.60	7012			
" " (D) " "	16 d							(465.80) 483.30	(59.70) 58.70	7076			
Conveyor #15 (A) Yr 25	16 a							(463.20) 472.90	(60.50) 62.00	6884			
" " (B) " "	16 b							(464.10) 476.30	(60.20) 60.90	6948			
" " (C) " "	16 c							(465.00) 479.80	(59.90) 59.60	7012			
" " (D) " "	16 d							(465.80) 483.30	(59.70) 58.70	7076			

Date ______

TABLE 1[illegible] 3 (Cont'd)

TSP Emissions Input for Air [illegible] Modeling of Tract C-[illegible]

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr 24 hr/Ann	Stack Ht. (m) ft.	Exit Temp. (°K) °F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200) Grid 50 Grid	Y Coord. (200) Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Spent Shale Disp. to & over (32&41) Stockpile (G) Yr 10	32 'g	0.474 / 0.286	(10)	(288)	(15)	(15)		(467.20) 489.00	(56.20) 44.80	7140	0	(5)	
" " " (H) " "	32 'h	0.474 / 0.286						(467.00) 488.10	(55.30) 41.30				
" " " " (I) " "	32 'i	0.474 / 0.286						(466.90) 487.40	(54.40) 37.60				
" " " " (J) " "	32 'j	0.474 / 0.286						(466.60) 486.60	(53.60) 34.30				
Spent Shale Disp. to & over Stockpile (32&41)(A) Yr 15	32 'a	0.591 / 0.358						(463.60) 474.20	(61.30) 65.20				
" " " (B) " "	32 'b	0.591 / 0.358						(464.40) 477.60	(61.00) 64.00				
" " " (C) " "	32'c	0.591 / 0.358						(465.30) 481.00	(60.70) 63.00				
" " " (D) " "	32'd	0.591 / 0.358						(467.60) 490.40	(60.50) 61.80				
" " " (E) " "	32'e	0.591 / 0.358						(467.00) 488.00	(60.20) 60.60				
" " " (F) " "	32'f	0.591 / 0.358						(467.00) 491.40	(59.90) 59.50				

Date ____________

TABLE 1' ˀ (Cont'd)

Run Group ____________

TSP Emissions Input for Air Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	SO_2 Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200)Grid 50 Grid	Y Coord. (200)Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Conveyor #15b Transfer Pt. Yr 10	25	(0.829)	(10)	(288)	(15)	(10)		(462.40) 469.60	(54.90) 39.50	7140	0	(5)	
" " Yr 15	25	↓		↓	↓	↓		(466.60) 486.50	(59.40) 57.70	↓	↓	↓	
" " Yr 25	25	↓		↓	↓	↓		(466.60) 486.50	(59.40) 57.70	↓	↓	↓	
Spent Shale Disposal Load-in & Out (30&31) Yr 10	30'	(1.737)	(0.00)	↓	(1)	(1)		(469.40) 469.60	(54.90) 39.50	↓	↓	↓	
" " " " Yr 15	30'	↓		↓	↓	↓		(466.60) 486.50	(59.40) 57.70	↓	↓	↓	
" " " " Yr 25	30'	↓		↓	↓	↓		(467.60) 490.40	(66.10) 84.40	↓	↓	↓	
Spent Shale Disp. to & over (32&41) Stockpile (A) Yr 10	32'a	(0.177) / (0.107)		↓	(15)	(15)		(463.40) 473.70	(55.10) 40.40	↓	↓	↓	
" " (B) " "	32'b	↓		↓	↓	↓		(464.40) 477.40	(55.40) 41.40	↓	↓	↓	
" " (C) " "	32'c	↓		↓	↓	↓		(465.30) 481.30	(55.70) 42.90	↓	↓	↓	
" " (D) " "	32'd	↓		↓	↓	↓		(466.30) 485.10	(55.90) 43.70	↓	↓	↓	
" " (E) " "	32'e	(0.474) / (0.286)		↓	↓	↓		(467.60) 490.50	(58.00) 51.80	↓	↓	↓	
" " (F) " "	32'f	↓		↓	↓	↓		(467.50) 489.80	(57.10) 48.40	↓	↓	↓	

TAB 11.3 (Cont'd)
TSP Emissions Input for A Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr 24 Hr/Ann	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200)Grid 50 Grid	Y Coord. (200)Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Spent Shale Disp. to & over Stockpile(32&41) (A) Yr 25	32'a	(0.215) (0.130)	(10)	(288)	(15)	(15)		(467.30) 489.30	(66.40) 85.60	7140	0	(5)	
" " " (B) " "	32'b	(0.215) (0.130)						(466.60) 486.60	(67.00) 88.00				
" " " (C) " "	32'c	(0.215) (0.130)						(465.90) 483.80	(67.60) 90.50				
" " " (D) " "	32'd	(0.215) (0.130)						(464.10) 476.20	(66.30) 85.40				
" " " (E) " "	32'e	0.583 0.353						(464.80) 479.10	(67.10) 88.30				
" " " (F) " "	32'f	0.583 0.353						(465.50) 481.90	(67.90) 91.40				
" " " (G) " "	32'g	0.583 0.353						(466.50) 486.10	(68.60) 94.30				
" " " (H) " "	32'h	0.583 0.353						(466.90) 487.70	(69.30) 97.30				

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr 24 hr/Ann	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200) Grid 50 Grid	Y Coord. (200) Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Spent Shale Pile (A) Yr 10	33a	(4.55) / (0.295)	(10)	(288)				(467.20) 488.70	(57.30) 49.00	6960	(243.84) 800	(5)	
" " " (B) " "	33b	(2.59) / (0.166)	↓	↓				(467.00) 487.90	(56.30) 45.40	6980	(182.88) 600	↓	
" " " (C) " "	33c	(2.59) / (0.166)	↓	↓				(467.00) 487.40	(55.40) 41.70	7000	(182.88) 600	↓	
" " " (D) " "	33d	(2.59) / (0.166)	↓	↓				(466.60) 486.20	(54.50) 38.10	7035	(182.88) 600	↓	
" " " (E) " "	33e	(1.15) / (0.074)	↓	↓				(466.40) 485.50	(53.90) 35.60	7060	(121.92) 400	↓	
" " " (F) " "	33f	(1.15) / (0.074)	↓	↓				(466.30) 485.00	(53.30) 33.20	7080	(121.92) 400	↓	
" " " (G) " "	33g	(0.97) / (0.064)	↓	↓				(466.30) 485.00	(52.70) 30.70	7100	(113.39) 372	↓	

Dat ____________ T' E 11.3 (Cont'd) Run Group ________

TSP Emissions Input for A Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr 24 hr/Ann	Stack Ht. (m) ft.	Exit Temp. (°K) °F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200) Grid 50 Grid	Y Coord. (200) Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Spent Shale Pile (A) Yr 15	33a	(0.69) / (0.046)	(10)	(283)				(463.10) 472.30	(60.60) 62.40	6740	(94.49) 310	(5)	
" " " (B)" "	33b	(2.59) / (0.166)						(463.50) 474.00	(60.60) 62.40	6790	(182.88) 600		
" " " (C) " "	33c	(2.59) / (0.166)						(464.40) 477.70	(60.30) 61.20	6860	(182.88) 600		
" " " (D) " "	33d	(2.59) / (0.166)						(465.30) 481.30	(60.00) 60.00	6915	(182.88) 600		
" " " (E) " "	33e	(2.59) / (0.166)						(466.30) 485.00	(60.00) 60.00	6880	(182.88) 600		
" " " (F) " "	33f	(4.55) / (0.295)						(467.20) 488.70	(59.40) 57.60	6880	(243.84) 800		
Spent Shale Pile (A) Yr 25	33a	(2.59) / (0.166)						(466.60) 486.20	(68.80) 95.40	6600	(182.88) 600		
" " " (B) " "	33b	(0.69) / (0.043)						(466.10) 484.30	(68.80) 95.40	6680	(91.44) 300		
" " " (C) " "	33c	(0.69) / (0.043)						(466.60) 486.20	(68.40) 93.60	6580	(91.44) 300		
" " " (D) " "	33d	(4.55) / (0.295)						(465.30) 481.30	(67.60) 90.50	6700	(243.84) 800		
" " " (E) " "	33e	(0.69) / (0.043)						(464.80) 479.40	(67.60) 90.50	6680	(91.44) 300		
" " " (F) " "	33f	(4.55) / (0.295)						(464.10) 476.50	(66.40) 85.70	6780	(243.84) 800		

Date _

TABL' ˘.3 (Cont'd)

TSP Emissions Input for Air ,ity Modeling of Tract C-b

Run Group

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr 24 hr/Ann	Stack Ht. (m) ft.	Exit Temp. (^{o}K) ^{o}F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200) Grid 50 Grid	Y Coord. (200) Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Spent Shale Pile (G) Yr 25	33g	(1.15) / (0.074)	(10)	(288)				(463.80) 475.20	(65.80) 83.30	6800	(121.92) 400	(5)	
" " " (H) " "	33h	(0.69) / (0.045)						(463.70) 474.90	(65.40) 81.50	6800	(94.49) 310		
Raw Shale Pile (A) Yr 10	34a	(0.016) / (0.001)						(458.50) 454.00	(68.80) 95.40	6750	(35) 115		
" " " (B) " "	34b	(0.140) / (0.009)						(458.50) 454.00	(68.20) 92.90	6760	(122) 400		
" " " (C) " "	34c	(0.140) / (0.009)						(459.50) 458.00	(67.60) 90.50	6680	(122) 400		
" " " (D) " "	34d	(0.140) / (0.009)						(460.50) 462.00	(67.00) 88.00	6700	(122) 400		
" " " (E) " "	34e	(0.140) / (0.009)						(462.50) 470.00	(66.40) 85.60	6760	(122) 400		
Raw Shale Pile (A) Yr 15	34a	(0.016) / (0.001)						(459.00) 456.00	(68.50) 94.10	6760	(35) 115		
" " " (B) " "	34b	(0.032) / (0.002)						(459.50) 458.00	(68.40) 93.50	6700	(61) 200		
" " " (C) " "	34c	(0.032) / (0.002)						(460.50) 462.00	(68.20) 92.90	6640	(61) 200		
" " " (D) " "	34d	(0.140) / (0.009)						(461.50) 466.00	(67.90) 91.70	6680	(122) 400		
" " " (E) " "	34e	(0.032) / (0.002)						(463.50) 474.00	(67.90) 91.70	6720	(61) 200		

Dat ____________ T' ~ 11.3 (Cont'd) Run Group ________

TSP Emissions Input for A' Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr 24 hr/Ann	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200) Grid 50 Grid	Y Coord. (200) Grid 50 Grid	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Raw Shale Pile (F) Yr 15	34f	(0.032) / (0.002)	(10)	(288)				(464.50) 478.00	(67.90) 91.70	6740	(61) 200	(5)	
" " " (G) " "	34g	(0.032) / (0.002)	↓	↓				(464.50) 478.00	(67.60) 90.50	6740	(61) 200	↓	
" " " (H) " "	34h	(0.140) / (0.002)						(465.50) 482.00	(67.60) 90.50	6780	(122) 400		
" " " (I) " "	34i	(0.032) / (0.002)						(467.50) 490.00	(67.60) 90.50	6780	(61) 200		
" " " (J) " "	34j	(0.032) / (0.002)						(468.50) 494.00	(67.60) 90.50	6800	(61) 200		
" " " (K) " "	34k	(0.032) / (0.002)	↓	↓				(468.00) 492.00	(67.30) 89.30	6800	(61) 200	↓	

Date ______________

T*BLE 11.3 (Cont'd)

TSP Emissions Input for Quality Modeling of Tract C-b

Run Group ______

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr (24hr/Ann)	Stack Ht. (m) ft.	Exit Temp. (°K) °F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Raw Shale Pile Yr 25	34a	(.140) / (0.0089)	(10)	(288)				(469.50) 498.00	(70.70) 102.70	6700	(122) 400	(5)	
" " " "	34b	(.016) / (0.0009)						(470.00) 500.00	(70.50) 102.10	6700	(35) 115		
" " " "	34c	(.032) / (0.0022)						(470.50) 502.00	(70.40) 101.50	6700	(61) 200		
" " " "	34d	(.032) / (0.0022)						(471.50) 506.00	(70.40) 101.50	6700	(61) 200		
" " " "	34e	(.140) / (0.0089)						(471.50) 506.00	(70.70) 102.70	6800	(122) 400		
" " " "	34f	(.032) / (0.0022)						(472.50) 510.00	(70.40) 101.50	6720	(61) 200		
" " " "	34g	(.140) / (0.0089)						(473.50) 514.00	(70.40) 101.50	6720	(122) 400		
" " " "	34h	(.032) / (0.0022)						(473.00) 512.00	(70.10) 100.20	6720	(61) 200		

TABLE 11.3 (Cont'd)

TSP Emissions Input f. .ir Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Conveyor #16 (A) Yr 25	37a	(0.009)	(2)	(288)	(1)	(1)		(467.50) 489.90	(65.10) 80.40	7140	0	(5)	
" " (B) " "	37b							(467.30) 489.40	(64.10) 76.30				
" " (C) " "	37c							(467.20) 488.80	(63.20) 72.70				
" " (D) " "	37d							(467.00) 488.20	(62.20) 68.70				
" " (E) " "	37e							(466.90) 487.70	(61.20) 64.80				
" " (F) " "	37f							(466.80) 487.30	(60.30) 61.00				

'E 11.3 (Cont'd)
TSP Emissions Input for Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Topsoil Removal @ 10 Yr Spent Shale Pile (A)	38a	(0.048)	(10)	(288)				(468.10) 492.30	(57.90) 51.50	6980	(122) 400	(5)	
" " (B)	38b	↓	↓	↓				(467.90) 491.70	(57.30) 49.00	7000	(122) 400	↓	
" " (C)	38c							(467.80) 491.10	(56.60) 46.60	7020	(122) 400		
" " (D)	38d							(467.80) 491.10	(56.00) 44.20	7020	(122) 400		
" " (E)	38e							(467.50) 489.90	(55.40) 41.70	7040	(122) 400		
" " (F)	38f							(467.50) 489.90	(54.80) 39.30	7060	(122) 400		
" " (G)	38g	(0.014)						(467.20) 488.70	(54.80) 39.30	7060	(61) 200		
" " (H)	38h	(.048)						(467.20) 488.70	(54.20) 36.80	7080	(122) 400		
" " (I)	38i	↓						(466.90) 487.40	(53.60) 34.40	7080	(122) 400		
" " (J)	38j							(466.60) 486.20	(53.00) 32.00	7080	(122) 400		
" " (K)	38k	(.014)						(466.30) 485.00	(52.70) 30.70	7100	(61) 200		

Date ______

TA[illegible] 11.3 (Cont'd)

TSP Emissions Input for Ai[illegible]uality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Topsoil Removal @ 15 Yr Spent Shale Pile (A)	38a	(.012)	(10)	(288)				(463.80) 475.20	(61.80) 67.30	6760	(61) 200	(5)	
" " " (B)	38b	(.012)						(464.10) 476.50	(61.80) 67.30	6780	(61) 200		
" " " (C)	38c	(.109)						(464.40) 477.70	(61.50) 66.10	6800	(183) 600		
" " " (D)	38d	(.109)						(465.30) 481.30	(61.20) 64.90	6860	(183) 600		
" " " (E)	38e	(.109)						(466.30) 485.00	(60.90) 63.70	6900	(183) 600		
" " " (F)	38f	(.109)						(467.20) 488.70	(60.60) 62.40	6900	(183) 600		

E 11.3 (Cont'd)

TSP Emissions Input for ... Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (°K) °F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Topsoil Removal @ 25 Yr Spent Shale Pile (A)	38a	(.012)	(10)	(288)				(466.60) 486.20	(69.80) 99.00	6620	(61) 200	(5)	
" " " (B)	38b	(.109)						(465.60) 482.60	(69.10) 96.60	6720	(183) 600		
" " " (C)	38c	(.012)						(465.60) 482.60	(68.80) 95.40	6700	(61) 200		
" " " (D)	38d	(.048)						(465.00) 480.10	(69.10) 96.60	6780	(122) 400		
" " " (E)	38e	(.109)						(464.70) 478.90	(68.20) 92.90	6760	(183) 600		
" " " (F)	38f	(.012)						(464.70) 478.90	(67.90) 91.70	6720	(61) 200		
" " " (G)	38g	(.048)						(464.10) 476.50	(68.20) 92.90	6820	(122) 400		
" " " (H)	38h	(.109)						(463.80) 475.20	(67.30) 89.30	6840	(183) 600		

Date ______________

TABLE 11.3 (Cont'd)
TSP Emissions Input for Air Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (°K) °F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Topsoil Dumping & Scraping @ Spent Shale Pile 10 Yr	42a	(.039)	(10)	(288)				(466.60) 486.20	(57.90) 51.50	6880	(122) 400	(5)	
" " " "	42b							(466.60) 486.20	(57.30) 49.00	6900	(122) 400		
" " " "	42c	(.010)						(466.90) 487.40	(57.00) 47.80	6920	(61) 200		
" " " "	42d	(.039)						(466.30) 485.00	(56.60) 46.60	6940	(122) 400		
" " " "	42e							(466.30) 485.00	(56.00) 44.20	6960	(122) 400		
" " " "	42f							(466.30) 485.00	(55.40) 41.70	6980	(122) 400		
" " " "	42g							(465.90) 483.80	(54.80) 39.30	7020	(122) 400		
" " " "	42h							(465.90) 483.80	(54.20) 36.80	7040	(122) 400		
" " " "	42i							(465.90) 483.80	(53.60) 34.40	7060	(122) 400		
" " " "	42j							(465.90) 482.60	(53.00) 32.00	7100	(122) 400		
" " " "	42k	(.010)						(465.90) 483.80	(52.70) 30.70	7120	(61) 200		

Dat ____

TABLE 11.3 (Cont'd)
TSP Emissions Input for Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (°K) °F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Topsoil Dumping & Scraping @ Spent Shale Pile 15 Yr	42a	(.010)	(10)	(288)				(462.60) 470.40	(60.60) 62.40	6790	(61) 200	(5)	
" " " "	42b	(.039)	↓	↓				(462.90) 471.60	(60.00) 60.00	6760	(122) 400	↓	
" " " "	42c	(.010)	↓	↓				(463.50) 474.00	(60.30) 61.20	6800	(61) 200	↓	
" " " "	42d	(.039)	↓	↓				(463.50) 474.00	(59.70) 58.80	6830	(122) 400	↓	
" " " "	42e	↓	↓	↓				(464.10) 476.50	(59.70) 58.80	6880	(122) 400	↓	
" " " "	42f	↓	↓	↓				(464.70) 478.90	(59.70) 58.80	6900	(122) 400	↓	
" " " "	42g	↓	↓	↓				(465.30) 481.30	(59.40) 57.60	6940	(122) 400	↓	
" " " "	42h	↓	↓	↓				(465.90) 483.80	(59.10) 56.30	6960	(122) 400	↓	
" " " "	42i	↓	↓	↓				(466.60) 486.20	(59.10) 56.30	6900	(122) 400	↓	
" " " "	42j	↓	↓	↓				(467.20) 488.70	(58.80) 55.10	6900	(122) 400	↓	
" " " "	42k	↓	↓	↓				(467.80) 491.10	(58.80) 55.10	6920	(122) 400	↓	

Date ________________

TA' 11.3 (Cont'd)
TSP Emissions Input for Air Quality Modeling of Tract C-b

Run Group ____________ ____________

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Topsoil Dumping & Scraping & Spent Shale Pile 25 Yr	42a	(.021)	(10)	(288)				(467.50) 489.90	(68.80) 95.40	6680	(91) 300	(5)	
" " " "	42b	(.039)						(467.20) 488.70	(68.20) 92.90	6680	(122) 400		
" " " "	42c	(.021)						(467.20) 488.70	(67.80) 91.10	6690	(91) 300		
" " " "	42d	(.039)						(466.60) 486.20	(60.00) 60.00	6640	(122) 400		
" " " "	42e	(.021)						(466.60) 486.20	(67.20) 88.70	6680	(91) 300		
" " " "	42f	(.039)						(465.90) 483.80	(67.00) 88.00	6600	(122) 400		
" " " "	42g	(.021)						(465.90) 483.80	(66.60) 86.20	6610	(91) 300		
" " " "	42h	(.039)						(465.30) 481.30	(66.40) 85.60	6740	(122) 400		
" " " "	42i	(.021)						(465.30) 481.30	(65.90) 83.80	6740	(91) 300		
" " " "	42j	(.039)						(464.70) 478.80	(65.80) 83.20	6740	(122) 400		
" " " "	42k	(.021)						(464.70) 478.90	(65.30) 81.30	6740	(91) 300		

E 11.3 (Cont'd)
TSP Emissions Input for . . Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g 50 g	Y Coord. (200 g) 50·g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Topsoil Dumping & Scraping @ Spent Shale Pile 25 Yr	421	(.039)	(10)	(288)				(464.10) 476.50	(65.20) 80.70	6780	(122) 400	(5)	
" " " "	42m	(.021)	↓	↓				(464.00) 475.80	(65.20) 80.70	6800	(47) 155	↓	
Emission to & over Raw Shale Pile Yr 10 (A)	45a	(.012) / (.008)	(10)	(288)	(30)	(15)		(460.10) 460.30	(67.7) 91.00	6710	0	(5)	
" " " (B)	45b	(.019) / (.011)						(459.90) 459.40	(68.40) 93.70	6760			
" " " (C)	45c	(.019) / (.011)						(460.60) 462.60	(67.30) 89.30	6700			
Emission to & Over Raw Shale Pile Yr 15 (A)	45a	(.017) / (.010)						(459.70) 458.80	(68.50) 94.10	6760			
" " " (B)	45b	(.017) / (.010)						(461.40) 465.50	(67.50) 90.20	6730			
" " " (C)	45c	(.017) / (.010)						(460.00) 460.00	(68.00) 92.20	6740			
Emission to & over Raw Shale Pile Yr 25 (A)	45a	(.025) / (.015)						(462.90) 471.60	(69.90) 99.50	6710			
" " " (B)	45b	(.025) / (.015)	↓	↓	↓	↓		(463.50) 474.00	(70.50) 101.90	6710	↓	↓	

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 q) 50 g)	Y Coord. (200 q) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Topsoil Dumping, Scraping, Shaping @ Raw Shale Pile Yr 10	47a	0.017	(10)	(288)	(30)	(15)		(459.50) 458.20	(69.30) 97.30	6720	0	(5)	
" " " "	47b							(460.10) 460.30	(68.50) 94.00	6810			
" " " "	47c							(460.50) 462.10	(67.70) 90.80	6900			
" " " "	47d							(461.60) 464.60	(66.90) 87.60	6940			
" " " "	47e							(461.70) 466.90	(66.10) 84.50	6980			
" " " " YR 15	47a	0.014						(459.40) 457.40	(68.80) 95.20	6740			
" " " "	47b							(460.10) 460.50	(68.60) 94.40	6760			
" " " "	47c							(460.90) 463.70	(68.40) 93.50	6780			
" " " "	47d							(461.70) 466.90	(68.10) 92.40	6800			
" " " "	47e							(462.50) 470.20	(67.90) 91.70	6820			
" " " "	47f							(463.30) 473.40	(67.70) 90.60	6840			

Date ______

Run Group ______

T/ 11.3 (Cont'd)
TSP Emissions Input for Ai ,uality Modeling of Tract C-b

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (^oK) ^oF	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Topsoil Dumping, Scraping, & Shaping @ Raw Shale Pile Yr 25	47a	(0.042)	(10)	(288)	(30)	(15)		(463.60) 474.30	(71.20) 104.90	6760	0	(5)	
" " " "	47b							(464.40) 477.40	(71.00) 103.90	6830			
Vehicular Emission over Raw Shale Pile Yr 10	49	(0.002)						(460.20) 461.00	(67.90) 91.50	6710			
" " " Yr 15	49							(460.00) 460.00	(68.00) 92.20	6740			
" " " (A) Yr 25	49a	(0.001)						(463.50) 473.80	(70.90) 103.50	6930			
" " " (B) Yr 25	49b							(464.20) 476.80	(70.60) 102.50	6930			

Date ____________

T/ 11.3 (Concluded)

TSP Emissions Input for Air Quality Modeling of Tract C-b

Run Group ____________

SOURCE I. D.	Source No.	TSP Emission Rate (gm/sec) lb/hr	Stack Ht. (m) ft.	Exit Temp. (°K) °F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. (200 g) 50 g	Y Coord. (200 g) 50 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Topsoil Removal @ 10 Yr Raw Shale Pile (A)	50a	(0.009)	(10)	(288)	(30)	(15)		(459.40) 457.40	(68.20) 92.60	6740	0	(5)	
" " (B)	50b							(459.90) 459.70	(68.00) 91.90	6755			
" " (C)	50c							(460.50) 462.00	(67.10) 88.50	6770			
" " (D)	50d							(461.10) 464.50	(66.30) 85.30	6780			
" " @ 15 Yr (A)	50a							(460.20) 460.70	(68.20) 92.60	6700			
" " " (B)	50b							(461.00) 464.00	(67.90) 91.70	6740			
" " " (C)	50c							(461.80) 467.30	(67.60) 90.50	6780			
" " " (D)	50d							(462.60) 470.50	(67.50) 89.90	6820			
" " " (A) 25 Yr	50a	(0.011)						(463.10) 472.20	(70.60) 102.40	6700			
" " " (B) "	50b							(463.60) 474.30	(70.30) 101.20	6720			
" " " (C) "	50c							(464.20) 476.80	(70.40) 101.60	6750			

Date ___ ______ ______

Run Group ______ ______

Page 1 of 1

TABLE 1.

NOX, CO Emissions Input for Air Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	NOX Emission Rate (gm/sec) lb/hr Annual	CO Emission Rate (gm/sec) lb/hr 1hr/8hr	Stack Ht. (m) ft.	Exit Temp. (°K) °F	Exit Speed (m/sec) ft/sec	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	Y Coord.	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Mine Exhaust Shaft #1	43	(16.80)	(30.01) / (13.81)	(30)	(294)	(19.1)		(1623			(0)		Plume rise calc. from Eqs (13-15), Table 4
Mine Exhaust Shaft #2	44	(16.80)	(30.01) / (13.81)	(30)	(294)	(19.1)		(1623)					
FGD Stack #1	52	(174.5)		(34)	(346)	(36.6)	(4.82)	(637)					
" " #2	53												
" " #3	54												
" " #4	55												
" " #5	56												
11 Temp. Power Gems	58	(1.30)	(6.20) / (6.20)	(6.10)	(845)		(0.85)	(113)					
Cement Batch Plant Boiler	60	(0.035)	(0.03) / (0.03)	(5.50)	(589)		(0.51)	(3.21)					
Lurgi Group 1 (U1&5)	61	(13.86)	(84.58) / (84.58)	(30)	(433)	(36.6)		(189.7)					
Lurgi Group 2 (U2,3,6&7)	62	(20.79)	(126.87) / (126.87)					(284.5)					
Lurgi Group 3 (U4&8)	63	(13.86)	(84.58) / (84.58)					(189.7)					

TABLE 11.5

TSP Mass Distributions by Source

Source No.	Source I.D.	Particle Mass Distribution (%) for Average Particle Size				
		0-10 μ (5 μ avg)	10-100 μ (55 μ avg)	100-500 μ (300 μ avg)	500-2000 μ (1250 μ avg)	2000 μ Nom 7000 μ avg
34	Nom Raw Shale Pile	0.1	0.3	0.9	2.2	96.5
20, 21, 22	1/2" Raw Shale	1.0	3.0	6.5	20.0	69.5
32, 38, 43	Topsoil (Fug. Dust)	15.0	37.6	33.4	12.0	2.0
33	Spent Shale Pile	46.0	47.0	6.0	1.0	0
61, 62, 63	Lurgi Stack	53.0	46.0	1.0	0	0
43, 44	Mine Vents	36.0	50.0	13.0	1.0	0

Date

TABLE 6

Secondary Emissions Input for Air Quality Modeling of Tract C-b

Run Group

SOURCE I. D.	Source No.	SO_2 Emission Rate	TSP Emission Rate	NOX Emission Rate	CO Emission Rate	Stack Height	Actual Vol. Flow	X Coord.	Y Coord.	Source Elev.	Source Width	Input Plume Rise	REMARKS
		(gm/sec) 24hr&Ann	(gm/sec) 24hr&Ann	(gm/sec) Annual	(gm/sec) 1hr/8hr	(m) ft.	(m^3/sec) WACFM	1000 q	1000 q	ft.	(m) ft.	(m) ft.	
VE Emission on PC Rd	64a	(0.0137)	(0.007)	(0.0329)	(0.0101) / (0.0052)	(1)		457.50	63.80	6480	0	(5)	
" " "	64b							457.80	65.50	6300			
" " "	64c							459.30	64.90	6320			
" " "	64d							460.60	64.10	6380			
" " "	64e							462.00	63.80	6460			
" " "	64f							463.40	63.20	6340			
" " "	64g							464.90	62.70	6500			
" " "	64h							465.90	61.50	6500			
" " "	64i							467.10	61.10	6520			
" " "	64j							468.20	60.00	6600			
" " "	64k							469.70	59.80	6680			
" " "	64l							471.10	60.00	6780			

Da' ____________ 1 : 11.6 (Cont'd) Run Group ______ ______

Secondary Emissions Input for Air Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	SO_2 Emission Rate (gm/sec) 24hr&Ann	TSP Emission Rate (gm/sec) 24hr&Ann	NOX Emission Rate (gm/sec) Annual	CO Emission Rate (gm/sec) 1 hr/8 hr	Stack Height (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. 1000 g	Y Coord. 1000 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
VE Emission on PC Rd	64m	(0.0137)	(0.007)	(0.0329)	(0.0101) / (0.0052)	(1)		472.50	60.30	6700	0	(5)	
" " "	64n							473.80	59.50	6720			
" " "	64o							475.00	58.10	6800			
" " "	64p							476.10	57.60	6820			
" " "	64q							476.90	56.30	6860			
" " "	64r							476.90	55.00	6900			
" " "	64s							477.50	53.70	7260			
" " "	64t							478.80	52.70	7100			
" " "	64u							479.70	52.00	7260			
" " "	64v							481.40	52.50	7200			
" " "	64w							482.70	53.00	7220			

Date ______

TABLE 6 (Cont'd)

Secondary Emissions Input for Air Quality Modeling of Tract C-b

Run Group ______ ______

SOURCE I. D.	Source No.	SO_2 Emission Rate (gm/sec) 24 hr&Ann	TSP Emission Rate (gm/sec) 24 hr&Ann	NOX Emission Rate (gm/sec) Annual	CO Emission Rate (gm/sec) 1 hr/8 hr	Stack Height (m)	Actual Vol. Flow (m^3/sec) WACFM	X Coord. 1000 g	Y Coord. 1000 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
VE Emission from Rifle to Rio Blanco Store	66a	(1.27)	(1.10)	(11.30)	(46.3) / (28.9)	(5)		496.10	29.70	5345	0	(10)	
" " "	66b	(0.009)	(0.0048)	(0.0288)	(0.0076) / (0.0037)	(1)		496.10	30.70	5380		(5)	
" " "	66c							496.60	32.00	5420			
" " "	66d							497.20	33.50	5520			
" " "	66e							497.30	35.10	5600			
" " "	66f							496.70	36.50	5680			
" " "	66g							495.40	37.40	5753			
" " "	66h							494.30	38.50	5860			
" " "	66i							493.00	39.50	5938			
" " "	66j							491.70	40.30	6120			
" " "	66k							490.50	41.30	6200			
" " "	66l							489.00	42.20	6360			

Date ______________

TAB 1.6 (Cont'd)

Secondary Emissions Input for Air Quality Modeling of Tract C-b

Run Group ________ ________

SOURCE I. D.	Source No.	SO_2 Emission Rate (gm/sec) 24hr&Ann	TSP Emission Rate (gm/sec) 24hr&Ann	NOX Emission Rate (gm/sec) Annual	CO Emission Rate (gm/sec) 1 hr/8hr	Stack Height (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. 1000 g	Y Coord. 1000 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
VE Emission from Rifle to Rio Blanco Store	66m	(0.009)	(0.0048)	(0.0288)	(0.0076) / (0.0037)	(1)		489.00	42.20	6360	0	(5)	
" " "	66n							487.90	43.30	6540			
" " "	66o							485.80	45.70	6800			
" " "	66p							484.80	46.90	7000			
" " "	66q							483.90	48.30	7280			
" " "	66r							483.40	49.80	7467			
" " "	66s							483.00	51.40	7258			
" " "	66t							482.80	53.00	7253			

Date ______

TABLE 11.6 (Cont'd)

Secondary Emissions Input for Air Quality Modeling of Tract C-b

Run Group ______

SOURCE I. D.	Source No.	SO_2 Emission Rate	TSP Emission Rate	NOX Emission Rate	CO Emission Rate	Stack Diameter	Actual Vol. Flow	X Coord.	Y Coord.	Source Elev.	Source Width	Input Plume Rise	REMARKS
		(gm/sec) 24hr&Ann	(gm/sec) 24hr&Ann	(gm/sec) Annual	(gm/sec) 1hr/8hr	(m) ft.	(m^3/sec) WACFM	1000 g	1000 g	ft.	(m) ft.	(m) ft.	
VE Emission from Rio Blanco Store to Meeker	67a	(0.0016)	(0.0021)	(0.0041)	(0.0014) / (0.0007)	(1)		482.60	54.50	7239	0	(5)	
" " "	67b							482.50	56.20	7360			
" " "	67c							482.50	57.80	7284			
" " "	67d							482.40	59.40	7200			
" " "	67e							482.20	61.00	7220			
" " "	67f							482.20	62.60	7220			
" " "	67g							482.20	64.30	7200			
" " "	67h							482.30	65.90	7230			
" " "	67i							482.30	67.50	7210			
" " "	67j							482.30	69.10	7260			
" " "	67k							482.30	70.70	7000			
" " "	67l							481.80	72.20	6980			

Date ____________

TABLE 11.6 (Cont'd)

Secondary Emissions Input for Air Quality Modeling of Tract C-b

Run Group ____________

SOURCE I. D.	Source No.	SO_2 Emission Rate (gm/sec) 24hr&Ann	TSP Emission Rate (gm/sec) 24hr&Ann	NOX Emission Rate (gm/sec) Annual	CO Emission Rate (gm/sec) 1hr/8hr	Stack (m)	Actual Vol. Flow (m^3/sec) WACFM	X Coord. 1000 g	Y Coord. 1000 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
VE Emission from Rio Blanco Store to Meeker	67m	(0.0016)	(0.0021)	(0.0041)	~~(0.0014)~~ (0.0007)	(1)		481.90	73.70	6791	0	(5)	
" " "	67n							481.60	75.30	6740			
" " "	67o							481.40	76.80	6610			
" " "	67p							481.50	78.30	6532			
" " "	67q							481.70	79.90	6520			
" " "	67r							481.70	81.40	6480			
" " "	67s							481.60	83.00	6200			
" " "	67t							482.30	84.40	6180			
" " "	67u							483.90	84.70	6200			
" " "	67v							485.00	85.80	6240			
" " "	67w	(0.15)	(0.29)	(2.27)	(10.9) (10.9)	(5)		486.30	86.30	6239		(10)	

Date ______

Run Group ______

TABLE 11.6 (Cont'd)

Secondary Emissions Input for Air Quality Modeling of Tract C-b

SOURCE I. D.	Source No.	SO_2 Emission Rate (gm/sec) 24 hr&Ann	TSP Emission Rate (gm/sec) 24 hr&Ann	NOX Emission Rate (gm/sec) Annual	CO Emission Rate (gm/sec) 1 hr/8 hr	Stack Diameter (m) ft.	Actual Vol. Flow (m^3/sec) WACFM	X Coord. 1000 g	Y Coord. 1000 g	Source Elev. ft.	Source Width (m) ft.	Input Plume Rise (m) ft.	REMARKS
Home Emissions Rifle, Colorado	65	(0.009)	(0.231)	(1.22)	(0.30) / (0.30)	(5)		496.10	29.70	5345	0	(10)	
Home Emissions Meeker, Colorado	68	(0.004)	(0.095)	(0.504)	(0.13) / (0.13)	(5)		486.30	86.30	6239	0	(10)	

TABLE 11.7

PRIMARY EMISSION SOURCE LOCATIONS AND ELEVATIONS

Source No.	Source Identification	Colorado Coordinates (N) ft.	Colorado Coordinates (E) ft.	Distance from Ref. Pt. In ft. (m) (N)	Distance from Ref. Pt. In ft. (m) (E)	Source Elevation In ft. (m)	Remarks
	Meteorological Tower Reference	180,000	1,237,700	-	-	-	Used as Modeling Origin
1'a	Conveyors #1-1A Combined	184,160	1,235,080	4,160 (1,268)	-2,620 (-799)	6,971 (2,125)	
1'b	Conveyors #1-1A Combined	184,050	1,235,420	4,050 (1,235)	-2,280 (-695)	6,999 (2,134)	
1'c	Conveyors #1-1A Combined	183,920	1,235,820	3,920 (1,195)	-1,880 (-573)	7,028 (2,143)	
3'	Conveyor #1, 1A, 2, 2A Combined Trans. Pt.	183,840	1,236,120	3,840 (1,171)	-1,580 (-482)	6,945 (2,117)	
5a	Conveyor #2	183,340	1,236,200	3,340 (1,018)	-1,500 (-457)	6,932 (2,113)	
5b	Conveyor #2	182,880	1,236,260	2,880 (878)	-1,440 (-439)	6,932 (2,113)	
5c	Conveyor #2	182,420	1,236,340	2,420 (738)	-1,360 (-415)	6,932 (2,113)	
6a	Conveyor #2A	183,400	1,236,260	3,400 (1,037)	-1,440 (-439)	6,932 (2,113)	
6b	Conveyor #2A	182,960	1,236,360	2,960 (902)	-1,340 (-409)	6,932 (2,113)	
6c	Conveyor #2A	182,510	1,236,500	2,510 (765)	-1,200 (-366)	6,932 (2,113)	
7'	Stacking Tower Load-Ins (7 & 8)	182,100	1,236,606	2,100 (640)	-1,094 (-334)	6,957 (2,121)	
9'	Stacking Tower Load-Ins (9 & 10)	181,998	1,236,405	1,998 (609)	-1,295 (-395)	6,957 (2,121)	
13	Conveyor #14 Transfer Pt.	183,872	1,236,141	3,872 (1,180)	-1,559 (-475)	6,945 (2,117)	
14	Transfer-Stacking Tower to Conveyor #3	182,100	1,236,606	2,100 (640)	-1,094 (-334)	6,836 (2,084)	
15	Transfer-Stacking Tower to Conveyor #3A	181,998	1,236,405	1,998 (609)	-1,295 (-395)	6,836 (2,084)	
17'a	Conveyors #3 & 3A (Combined)	181,940	1,236,740	1,940 (591)	-960 (-293)	6,930 (2,113)	
17'b	Conveyors #3 & 3A (Combined)	181,840	1,237,020	1,840 (561)	-680 (-207)	6,883 (2,098)	
19	Secondary & Tertiary Crushing	181,913	1,237,250	1,913 (583)	-450 (-137)	7,000 (2,134)	
20'	Conveyors #4 & 4A (Combined) (20 & 21)	181,980	1,237,340	1,980 (604)	-360 (-110)	6,922 (2,110)	
22	Conveyor #6	181,980	1,237,340	1,980 (604)	-360 (-110)	6,947 (2,117)	
23	Conveyor Transfer Area	182,194	1,237,381	2,194 (669)	-319 (-97)	6,980 (2,128)	
24	Conveyor #15 Transfer Pt.	180,525	1,239,240	525 (160)	1,540 (469)	6,820 (2,079)	
26	30k Ton Storage Silo Load-In	181,183	1,236,935	1,183 (361)	-756 (-23)	7,060 (2,152)	
27'	30k Ton Storage Silo Load-Out (27 & 28)	181,220	1,237,075	1,220 (372)	-625 (-191)	6,908 (2,106)	
29	Spent Shale Handling and Disposal Pt.	180,730	1,238,615	730 (223)	915 (279)	7,016 (2,138)	
43	Mine Exhaust Shaft #1	182,382	1,237,075	2,382 (726)	-625 (-191)	6,820 (2,079)	
44	Mine Exhaust Shaft #2	182,300	1,240,854	2,300 (701)	3,154 (962)	6,720 (2,049)	
52	FGD Stack #1	182,180	1,238,280	2,180 (665)	580 (177)	6,850 (2,088)	
53	FGD Stack #2	182,110	1,238,480	2,110 (643)	780 (238)	6,850 (2,088)	
54	FGD Stack #3	182,040	1,238,700	2,040 (622)	1,000 (305)	6,850 (2,088)	
55	FGD Stack #4	181,960	1,238,920	1,960 (598)	1,220 (372)	6,850 (2,088)	
56	FGD Stack #5	181,900	1,239,120	1,900 (579)	1,420 (433)	6,850 (2,088)	
58	Eleven Temp. Power Generators	185,200	1,234,100	5,200 (1,585)	-3,600 (-1,097)	6,828 (2,081)	
59	Cement Batch Plant	184,300	1,234,700	4,300 (1,311)	-3,000 (-915)	6,828 (2,081)	
60	Cement Batch Plant Boiler	184,300	1,234,700	4,300 (1,311)	-3,000 (-915)	6,828 (2,081)	
61	Lurgi Flue Gas Stacks U# 1 & 5	181,300	1,237,630	1,300 (396)	-70 (-21)	6,890 (2,100)	
62	Lurgi Flue Gas Stacks U# 2, 3, 6, 7	181,180	1,237,980	1,180 (360)	280 (85)	6,895 (2,102)	
63	Lurgi Flue Gas Stacks U# 4 & 8	181,080	1,238,250	1,080 (329)	550 (168)	6,900 (2,103)	

TABLE 11.7 (Cont'd)
PRIMARY EMISSION SOURCE LOCATIONS AND ELEVATIONS

Source No.	Source Identification	Colorado Coordinates (N) ft.	Colorado Coordinates (E) ft.	Distance from Ref. Pt. In ft. (m) (N)	Distance from Ref. Pt. In ft. (m) (E)	Source Elevation In ft. (m)	Remarks
11	Raw Shale Dump to Conv. #14 yr 10	185,000	1,237,640	5,000 (1,524)	-60 (-18)	6,740 (2,054)	
11	Raw Shale Dump to Conv. #14 yr 15	185,200	1,237,930	5,200 (1,585)	230 (70)	6,725 (2,050)	
11	Raw Shale Dump to Conv. #14 yr 25	186,240	1,239,340	6,240 (1,902)	2,240 (683)	6,710 (2,045)	
12a	Conveyor #14 (A) yr 10	184,260	1,236,570	4,260 (1,298)	-1,130 (-344)	6,840 (2,085)	
12b	" " (B) " "	184,630	1,237,100	4,630 (1,411)	-600 (-183)	6,800 (2,073)	
12a	" " (A) yr 15	184,180	1,236,540	4,180 (1,274)	-1,160 (-354)	6,800 (2,073)	
12b	" " (B) " "	184,560	1,236,980	4,560 (1,390)	-720 (-219)	6,790 (2,070)	
12c	" " (C) " "	184,850	1,237,450	4,850 (1,478)	-250 (-76)	6,710 (2,045)	
12a	" " (A) yr 25	184,220	1,236,570	4,220 (1,286	-1,130 (-344)	6,800 (2,073)	
12b	" " (B) " "	184,550	1,237,030	4,550 (1,387)	-670 (-204)	6,760 (2,060)	
12c	" " (C) " "	184,880	1,237,480	4,880 (1,487)	-220 (-67)	6,750 (2,057)	
12d	" " (D) " "	185,230	1,237,930	5,230 (1,594)	230 (70)	6,740 (2,054)	
12e	" " (E) " "	185,580	1,238,400	5,580 (1,701)	700 (213)	6,730 (2,051)	
12f	" " (F) " "	185,900	1,238,850	5,900 (1,798)	1,150 (351)	6,700 (2,042)	
16a	Conveyor #15 (A) yr 10	180,000	1,239,240	-0- -0-	1,540 (469)	6,860 (2,091)	
16b	" " (B) " "	179,420	1,239,240	-580 (-177)	1,540 (469)	6,910 (2,106)	
16c	" " (C) " "	178,900	1,239,250	-1,100 (-335)	1,550 (472)	6,960 (2,121)	
16d	" " (D) " "	178,360	1,239,260	-1,640 (-500)	1,560 (475)	7,000 (2,134)	
16e	" " (E) " "	177,780	1,239,260	-2,220 (-677)	1,560 (475)	7,050 (2,149)	
16f	" " (F) " "	177,190	1,239,260	-2,810 (-856)	1,560 (475)	7,090 (2,161)	
16a	" " (A) yr 15	180,320	1,239,820	320 (98)	2,120 (646)	6,884 (2,098)	
16b	" " (B) " "	180,140	1,240,380	140 (43)	2,680 (817)	6,948 (2,118)	
16c	" " (C) " "	179,940	1,240,950	-60 (-18)	3,250 (991)	7,012 (2,137)	
16d	" " (D) " "	179,780	1,241,520	-220 (-67)	3,820 (1,164)	7,076 (2,157)	
16a	" " (A) yr 25	180,320	1,239,820	320 (98)	2,120 (646)	6,884 (2,098)	
16b	" " (B) " "	180,140	1,240,380	140 (43)	2,680 (817)	6,948 (2,118)	
16c	" " (C) " "	179,940	1,240,950	-60 (-18)	3,250 (991)	7,012 (2,137)	
16d	" " (D) " "	179,780	1,241,520	-220 (-67)	3,820 (1,164)	7,076 (2,157)	
25	Conveyor #15 Trans. Pt. 10 yr	176,640	1,239,280	-3,360 (-1,024)	1,580 (482)	7,140 (2,176)	
25	" " " " 15 yr	179,615	1,242,050	-385 (-117)	4,350 (1,326)	7,140 (2,176)	
25	" " " " 25 yr	179,615	1,242,050	-385 (-117)	4,350 (1,326)	7,140 (2,176)	
30'	Spent Shale Disp. Pt. 10 yr	176,640	1,239,280	-3,360 (-1,024)	1,580 (482)	7,140 (2,176)	
30'	" " " " 15 yr	179,615	1,242,050	-385 (-117)	4,350 (1,326)	7,140 (2,176)	
30'	" " " " 25 yr	184,005	1,242,690	4,005 (1,221)	4,990 (1,521)	7,140 (2,176)	
32a'	Spent Shale Disp. to & Over Stockpile (32 & 41) (A) 10 yr	176,780	1,239,940	-3,220 (-981)	2,240 (683)	7,140 (2,176)	
32b'	" " " " " " (B) 10 yr	176,950	1,240,560	-3,050 (-930)	2,860 (872)	7,140 (2,176)	
32c'	" " " " " " (C) 10 yr	177,190	1,241,200	-2,810 (-856)	3,500 (1,067)	7,140 (2,176)	
32d'	" " " " " " (D) 10 yr	177,320	1,241,810	-2,680 (-817)	4,110 (1,253)	7,140 (2,176)	
32e'	" " " " " " (E) 10 yr	178,660	1,242,710	-1,340 (-408)	5,010 (1,527)	7,140 (2,176)	

TABLE 11.7 (Cont'd)

PRIMARY EMISSION SOURCE LOCATIONS AND ELEVATIONS

Source No.	Source Identification	Colorado Coordinates (N) ft.	Colorado Coordinates (E) ft.	Distance from Ref. Pt. In ft. (m) (N)	Distance from Ref. Pt. In ft. (m) (E)	Source Elevation In ft. (m)	Remarks
32f	Spent Shale Disp. to & over Stockpile (32 & 41) (F) 10 yr.	178,100	1,242,590	-1,900 -1,400 (-579)	4,890 (1,490)	7,140 (2,176)	
32g	" " " " " " (G) 10 yr.	177,500	1,242,450	-2,500 (-762)	4,750 (1,448)	7,140 (2,176)	
32h	" " " " " " (H) " "	176,930	1,242,310	-3,070 (-936)	4,610 (1,405)	7,140 (2,176)	
32i	" " " " " " (I) " "	176,330	1,242,200	-3,670 (-1,119)	4,500 (1,372)	7,140 (2,176)	
32j	" " " " " " (J) " "	175,780	1,242,060	-4,220 (-1,286)	4,360 (1,329)	7,140 (2,176)	
32a	" " " " " " (A) 15 yr.	180,860	1,240,030	860 (262)	2,330 (710)	7,140 (2,176)	
32b	" " " " " " (B) " "	180,660	1,240,580	660 (201)	2,880 (878)	7,140 (2,176)	
32c	" " " " " " (C) " "	180,490	1,241,150	490 (149)	3,450 (1,052)	7,140 (2,176)	
32d	" " " " " " (D) " "	180,300	1,242,710	300 (91)	5,010 (1,527)	7,140 (2,176)	
32e	" " " " " " (E) " "	180,100	1,242,290	100 (30)	4,590 (1,399)	7,140 (2,176)	
32f	" " " " " " (F) " "	179,920	1,242,850	-80 (-24)	5,150 (1,570)	7,140 (2,176)	
32'a	(A) 25 yr.	184,200	1,242,500	4,200 (1,280)	4,800 (1,463)	7,140 (2,176)	
32'b	" " " " " " (B) " "	184,600	1,242,060	4,600 (1,402)	4,360 (1,329)	7,140 (2,176)	
32'c	" " " " " " (C) " "	185,000	1,241,600	5,000 (1,524)	3,900 (1,189)	7,140 (2,176)	
32'd	" " " " " " (D) " "	184,160	1,240,360	4,160 (1,268)	2,660 (811)	7,140 (2,176)	
32'e	" " " " " " (E) " "	184,650	1,240,840	4,650 (1,417)	3,140 (957)	7,140 (2,176)	
32'f	" " " " " " (F) " "	185,150	1,241,300	5,150 (1,570)	3,600 (1,097)	7,140 (2,176)	
32'g	" " " " " " (G) " "	185,620	1,241,980	5,620 (1,713)	4,280 (1,305)	7,140 (2,176)	
32'h	" " " " " " (H) " "	186,120	1,242,250	6,120 (1,865)	4,550 (1,387)	7,140 (2,176)	
33a	Spent Shale Pile (A) 10 yr.	178,200	1,242,400	-1,800 (-549)	4,700 (1,433)	6,960 (2,121)	Source width 800' x 800'
33b	" " " (B) " "	177,600	1,242,280	-2,400 (-732)	4,580 (1,396)	6,980 (2,128)	" " 600' x 600'
33c	" " " (C) " "	177,000	1,242,200	-3,000 (-914)	4,500 (1,372)	7,000 (2,134)	" " 600' x 600'
33d	" " " (D) " "	176,400	1,242,000	-3,600 (-1,097)	4,300 (1,311)	7,035 (2,144)	" " 600' x 600'
33e	" " " (E) " "	176,000	1,241,880	-4,000 (-1,219)	4,180 (1,274)	7,060 (2,152)	" " 400' x 400'
33f	" " " (F) " "	175,600	1,241,800	-4,400 (-1,341)	4,100 (1,250)	7,080 (2,158)	" " 400' x 400'
33g	" " " (G) " "	175,200	1,241,800	-4,800 (-1,463)	4,100 (1,250)	7,100 (2,164)	" " 372' x 372'
33a	" " " (A) 15 yr.	180,400	1,239,720	400 (122)	2,020 (616)	6,740 (2,054)	" " 310' x 310'
33b	" " " (B) " "	180,400	1,240,000	400 (122)	2,300 (701)	6,790 (2,070)	" " 600' x 600'
33c	" " " (C) " "	180,200	1,240,600	200 (61)	2,900 (884)	6,860 (2,091)	" " 600' x 600'
33d	" " " (D) " "	180,000	1,241,200	-0- (0)	3,500 (1,067)	6,915 (2,108)	" " 600' x 600'
33e	" " " (E) " "	180,000	1,241,800	-0- (0)	4,100 (1,250)	6,880 (2,097)	" " 600' x 600'
33f	" " " (F) " "	179,600	1,242,400	-400 (-122)	4,700 (1,433)	6,880 (2,097)	" " 800' x 800'
33a	" " " (A) 25 yr.	185,800	1,242,000	5,800 (1,768)	4,300 (1,311)	6,600 (2,012)	" " 600' x 600'
33b	" " " (B) " "	185,800	1,241,680	5,800 (1,768)	3,980 (1,213)	6,680 (2,036)	" " 300' x 300'
33c	" " " (C) " "	185,520	1,242,00	5,520 (1,682)	4,300 (1,311)	6,580 (2,006)	" " 300' x 300'
33d	" " " (D) " "	185,000	1,241,200	5,000 (1,524)	3,400 (1,067)	6,700 (2,042)	" " 800' x 800'
33e	" " " (E) " "	185,000	1,240,880	5,000 (1,524)	3,180 (969)	6,680 (2,036)	" " 300' x 300'
33f	" " " (F) " "	184,220	1,240,400	4,220 (1,286)	2,700 (823)	6,780 (2,067)	" " 800' x 800'
33g	" " " (G) " "	183,820	1,240,200	3,820 (1,164)	2,500 (762)	6,800 (2,073)	" " 400' x 400'
33h	" " " (H) " "	183,520	1,240,140	3,520 (1,073)	2,440 (744)	6,800 (2,073)	" " 310' x 310'

TABLE 11.7 (Cont'd)
PRIMARY EMISSION SOURCE LOCATIONS AND ELEVATIONS

Source No.	Source Identification	Colorado Coordinates (N) ft.	Colorado Coordinates (E) ft.	Distance from Ref. Pt. In ft. (m) (N)	Distance from Ref. Pt. In ft. (m) (E)	Source Elevation In ft. (m)	Remarks
34a	Raw Shale Pile (A) 10 yr.	185,800	1,237,400	5,800 (1,768)	-300 (-91)	6,750 (2,057)	Source width 115' x 115'
34b	" " " (B) " "	185,400	1,237,400	5,400 (1,646)	-300 (-91)	6,760 (2,060)	" " 400' x 400'
34c	" " " (C) " "	185,000	1,237,600	5,000 (1,524)	-100 (-30)	6,680 (2,036)	" " 400' x 400'
34d	" " " (D) " "	184,600	1,237,800	4,600 (1,402)	100 (30)	6,700 (2,042)	" " 400' x 400'
34e	" " " (E) " "	184,200	1,238,200	4,200 (1,280)	500 (152)	6,760 (2,060)	" " 400' x 400'
34a	" " " (A) 15 yr.	185,600	1,237,500	5,600 (1,707)	-200 (-61)	6,760 (2,060)	" " 115' x 115'
34b	" " " (B) " "	185,500	1,237,600	5,500 (1,676)	-100 (-30)	6,700 (2,042)	" " 200' x 200'
34c	" " " (C) " "	185,400	1,237,800	5,400 (1,646)	100 (30)	6,640 (2,024)	" " 200' x 200'
34d	" " " (D) " "	185,200	1,238,000	5,200 (1,585)	300 (91)	6,680 (2,036)	" " 400' x 400'
34e	" " " (E) " "	185,200	1,238,400	5,200 (1,585)	700 (213)	6,720 (2,048)	" " 200' x 200'
34f	" " " (F) " "	185,200	1,238,600	5,200 (1,585)	900 (274)	6,740 (2,054)	" " 200' x 200'
34g	" " " (G) " "	185,000	1,238,600	5,000 (1,524)	900 (274)	6,740 (2,054)	" " 200' x 200'
34h	" " " (H) " "	185,000	1,238,800	5,000 (1,524)	1,100 (335)	6,780 (2,067)	" " 400' x 400'
34i	" " " (I) " "	185,000	1,239,200	5,000 (1,524)	1,500 (457)	6,780 (2,067)	" " 200' x 200'
34j	" " " (J) " "	185,000	1,239,400	5,000 (1,524)	1,700 (518)	6,800 (2,073)	" " 200' x 200'
34k	" " " (K) " "	184,800	1,239,300	4,800 (1,463)	1,600 (488)	6,800 (2,073)	" " 200' x 200'
34a	" " " (A) 25 yr.	187,000	1,239,600	7,000 (2,134)	1,900 (579)	6,700 (2,042)	" " 400' x 400'
34b	" " " (B) " "	186,900	1,239,700	6,900 (2,103)	2,000 (610)	6,700 (2,042)	" " 115' x 115'
34c	" " " (C) " "	186,800	1,239,800	6,800 (2,073)	2,100 (640)	6,700 (2,042)	" " 200' x 200'
34d	" " " (D) " "	186,800	1,240,000	6,800 (2,073)	2,300 (701)	6,700 (2,042)	" " 200' x 200'
34e	" " " (E) " "	187,000	1,240,000	7,000 (2,134)	2,300 (701)	6,680 (2,036)	" " 400' x 400'
34f	" " " (F) " "	186,800	1,240,200	6,800 (2,073)	2,500 (762)	6,720 (2,048)	" " 200' x 200'
34g	" " " (G) " "	186,800	1,240,400	6,800 (2,073)	2,700 (823)	6,720 (2,048)	" " 400' x 400'
34h	" " " (H) "	186,600	1,240,300	6,600 (2,012)	2,600 (792)	6,720 (2,048)	" " 200' x 200'
35	Conveyor #16 Transfer Pt. Yr 25	179,615	1,242,050	-385 (-117)	4,350 (1,326)	7,140 (2,176)	
36	" " " " Yr 25	184,005	1,242,690	4,005 (1,221)	4,990 (1,521)	7,140 (2,176)	
37a	Conveyor #16 (A) 25 yr.	183,340	1,242,600	3,340 (1,018)	4,900 (1,494)	7,140 (2,176)	
37b	" " (B) " "	182,680	1,242,520	2,680 (817)	4,820 (1,469)	7,140 (2,176)	
37c	" " (C) " "	182,080	1,242,420	2,080 (634)	4,720 (1,439)	7,140 (2,176)	
37d	" " (D) " "	181,420	1,242,320	1,420 (433)	4,620 (1,408)	7,140 (2,176)	
37e	" " (E) " "	180,780	1,242,240	780 (238)	4,540 (1,384)	7,140 (2,176)	
37f	" " (F) " "	180,160	1,242,180	160 (49)	4,480 (1,366)	7,140 (2,176)	
38a	Topsoil Removal @ Spent Shale Pile 10 yr.	178,600	1,243,000	-1,400 (-427)	5,300 (1,615)	6,980 (2,128)	Source Width 400' x 400'
38b	" " " " " " " "	178,200	1,242,900	-1,800 (-549)	5,200 (1,585)	7,000 (2,134)	" " 400' x 400'
38c	" " " " " " " "	177,800	1,242,800	-2,200 (-671)	5,100 (1,554)	7,020 (2,140)	" " 400' x 400'
38d	" " " " " " " "	177,400	1,242,800	-2,600 (-792)	5,100 (1,554)	7,020 (2,140)	" " 400' x 400'
38e	" " " " " " " "	177,000	1,242,600	-3,000 (-914)	4,900 (1,494)	7,040 (2,146)	" " 400' x 400'
38f	" " " " " " " "	176,600	1,242,600	-3,400 (-1,036)	4,900 (1,494)	7,060 (2,152)	" " 400' x 400'
38g	" " " " " " " "	176,600	1,242,400	-3,400 (-1,036)	4,700 (1,433)	7,060 (2,152)	" " 200' x 200'
38h	" " " " " " " "	176,200	1,242,400	-3,800 (-1,158)	4,700 (1,433)	7,080 (2,158)	" " 400' x 400'
38i	" " " " " " " "	175,800	1,242,200	-4,200 (-1,280)	4,500 (1,372)	7,080 (2,158)	" " 400' x 400'
38j	" " " " " " " "	175,400	1,242,000	-4,600 (-1,402)	4,300 (1,311)	7,080 (2,158)	" " 400' x 400'
38k	" " " " " " " "	175,200	1,241,800	-4,800 (1,463)	4,100 (1,250)	7,100 (2,164)	" " 200' x 200'

TABLE 11.7 (Cont'd)
PRIMARY EMISSION SOURCE LOCATIONS AND ELEVATIONS

Source No.	Source Identification	Colorado Coordinates (N) ft.	Colorado Coordinates (E) ft.	Distance from Ref. Pt. In ft. (m) (N)	Distance from Ref. Pt. In ft. (m) (E)	Source Elevation In ft. (m)	Remarks
38a	Topsoil Removal @ Spent Shale Pile 15 yr.	181,200	1,240,200	1,200 (366)	2,500 (762)	6,760 (2,060)	Source Width 200' x 200'
38b	" " " " " " " "	181,200	1,240,400	1,200 (366)	2,700 (823)	6,780 (2,067)	" " 200' x 200'
38c	" " " " " " " "	181,000	1,240,600	1.000 (305)	2,900 (884)	6,800 (2,073)	" " 600' x 600'
38d	" " " " " " " "	180,800	1,241,200	800 (244)	3,500 (1,067)	6,860 (2,091)	" " 600' x 600'
38e	" " " " " " " "	180,600	1,241,800	600 (183)	4,100 (1,250)	6,900 (2,103)	" " 600' x 600'
38f	" " " " " " " "	180,400	1,242,400	400 (122)	4,700 (1,433)	6,900 (2,103)	" " 600' x 600'
38a	Topsoil Removal @ Spent Shale Pile 25 yr.	186,400	1,242,000	6,400 (1,951)	4,300 (1,311)	6,620 (2,018)	Source Width 200' x 200'
38b	" " " " " " " "	186,000	1,241,400	6,000 (1,829)	3,700 (1,128)	6,720 (2,048)	" " 600' x 600'
38c	" " " " " " " "	185,800	1,241,400	5,800 (1,768)	3,700 (1,128)	6,700 (2,042)	" " 200' x 200'
38d	" " " " " " " "	186,000	1,241,000	6,000 (1,829)	3,300 (1,006)	6,780 (2,067)	" " 400' x 400'
38e	" " " " " " " "	185,400	1,240,800	5,400 (1,646)	3,100 (945)	6,760 (2,060)	" " 600' x 600'
38f	" " " " " " " "	185,200	1,240,800	5,200 (1,585)	3,100 (945)	6,720 (2,048)	" " 200' x 200'
38g	" " " " " " " "	185,400	1,240,400	5,400 (1,646)	2,700 (823)	6,820 (2,079)	" " 400' x 400'
38h	" " " " " " " "	184,800	1,240,200	4,800 (1,463)	2,500 (762)	6,840 (2,085)	" " 600' x 600'
42a	Topsoil Dumping & Scraping @ Spent Shale Pile 10 yr.	178,600	1,242,000	1,400 (-427)	4,300 (1,311)	6,880 (2,097)	Source Width 400' x 400'
42b	" " " " " " "	178,200	1,242,000	-1,800 (-549)	4,300 (1,311)	6,900 (2,103)	" " 400' x 400'
42c	" " " " " " "	178,000	1,242,200	-2,000 (-610)	4,500 (1,372)	6,920 (2,109)	" " 200' x 200'
42d	" " " " " " "	177,800	1,241,800	-2,200 (-671)	4,100 (1,250)	6,940 (2,115)	" " 400' x 400'
42e	" " " " " " "	177,400	1,241,800	-2,600 (-792)	4,100 (1,250)	6,960 (2,121)	" " 400' x 400'
42f	" " " " " " "	177,000	1,241,800	-3,000 (-914)	4,100 (1,250)	6,980 (2,128)	" " 400' x 400'
42g	" " " " " " "	176,600	1,241,600	-3,400 (-1,036)	3,900 (1,189)	7,020 (2,140)	" " 400' x 400'
42h	" " " " " " "	176,200	1,241,600	-3,800 (-1,158)	3,900 (1,189)	7,040 (2,146)	" " 400' x 400'
42i	" " " " " " "	175,800	1,241,600	-4,200 (-1,280)	3,900 (1,189)	7,060 (2,152)	" " 400' x 400'
42j	" " " " " " "	175,400	1,241,400	-4,600 (-1,402)	3,700 (1,128)	7,100 (2,164)	" " 400' x 400'
42k	" " " " " " "	175,200	1,241,600	-4,800 (-1,463)	3,900 (1,189)	7,120 (2,140)	" " 200' x 200'
42a	Topsoil Dumping & Scraping @ Spent Shale Pile 15 yr.	180,400	1,239,400	400 (122)	1,700 (518)	6,790 (2,070)	" " 200' x 200'
42b	" " " " " " "	180,000	1,239,600	0 (0)	1,900 (579)	6,760 (2,060)	" " 400' x 400'
42c	" " " " " " "	180,200	1,240,000	200 (61)	2,300 (701)	6,800 (2,073)	" " 200' x 200'
42d	" " " " " " "	179,800	1,240,000	-200 (-61)	2,300 (701)	6,830 (2,082)	" " 400' x 400'
42e	" " " " " " "	179,800	1,240,400	-200 (-61)	2,700 (823)	6,880 (2,097)	" " 400' x 400'
42f	" " " " " " "	179,800	1,240,800	-200 (-61)	3,100 (945)	6,900 (2,103)	" " 400' x 400'
42g	" " " " " " "	179,600	1,241,200	-400 (-122)	3,500 (1.067)	6,940 (2,115)	" " 400' x 400'
42h	" " " " " " "	179,400	1,241,600	-600 (-183)	3,900 (1,189)	6,960 (2,111)	" " 400' x 400'
42i	" " " " " " "	179,400	1,242,000	-600 (-183)	4,300 (1,311)	6,900 (2,103)	" " 400' x 400'
42j	" " " " " " "	179,200	1,242,800	-800 (-244)	4,700 (1,433)	6,900 (2,103)	" " 400' x 400'
42k	" " " " " " "	179,200	1,242,800	-800 (-244)	5,100 (1,554)	6,920 (2,109)	" " 400' x 400'

TABLE 11.7 (Cont'd)
PRIMARY EMISSION SOURCE LOCATIONS AND ELEVATIONS

Source No.	Source Identification	Colorado Coordinates (N) ft.	Colorado Coordinates (E) ft.	Distance from Ref. Pt. In ft. (m) (N)	Distance from Ref. Pt. In ft. (m) (E)	Source Elevation In ft. (m)	Remarks
42a	Topsoil Dumping & Scraping @ Spent Shale Pile 25 yr.	185,800	1,242,600	5,800 (1,768)	4,900 (1,494)	6,680 (2,036)	Source Width 300' x 300'
42b	" " " " " " "	185,400	1,242,400	5,400 (1,646)	4,700 (1,433)	6,680 (2,035	" " 400' x 400'
42c	" " " " " " "	185,100	1,242,400	5,100 (1,554)	4,700 (1,433)	6,690 (2,039)	" " 300' x 300'
42d	" " " " " " "	185,000	1,242,000	0 (0)	4,300 (1,311)	6,640 (2,024)	" " 400' x 400'
42e	" " " " " " "	184,700	1,242,000	4,700 (1,433)	4,300 (1,311)	6,680 (2,036)	" " 300' x 300'
42f	" " " " " " "	184,600	1,241,600	4,600 (1,402)	3,900 (1,189)	6,600 (2,012)	" " 400' x 400'
42g	" " " " " " "	184,300	1,241,600	4,300 (1,311)	3,900 (1,189)	6,610 (2,015)	" " 300' x 300'
42h	" " " " " " "	184,200	1,241,200	4,200 (1,280)	3,500 (1,067)	6,740 (2,054)	" " 400' x 400'
42i	" " " " " " "	183,900	1,241,200	3,900 (1,189)	3,500 (1,067)	6,740 (2,054)	" " 300' x 300'
42j	" " " " " " "	183,800	1,240,800	3,800 (1,158)	3,100 (945)	6,740 (2,054)	" " 400' x 400'
42k	" " " " " " "	183,500	1,240,800	3,500 (1,067)	3,100 (945)	6,740 (2,054)	" " 300' x 300'
42l	" " " " " " "	183,400	1,240,400	3,400 (1,036)	2,700 (823)	6,780 (2,067)	" " 400' x 400'
42m	" " " " " " "	183,400	1,240,300	3,400 (1,036)	2,600 (792)	6,800 (2,073)	" " 300' x 300'
45a	Emiss. To & Over Raw Shale Pile (A) 10 yr.	185,080	1,237,750	5,080 (1,548)	50 (15)	6,710 (2,045)	
45b	" " " " " " (B) "	185,530	1,236,600	5,530 (1,686)	-100 (-30)	6,760 (2,060)	
45c	" " " " " " (C) "	184,800	1,238,120	4,800 (1,463)	420 (128)	6,700 (2,042)	
45a	Emiss. To & Over Raw Shale Pile (A) 15 yr.	185,600	1,237,500	5,600 (1,707)	-200 (-61)	6,760 (2,060)	
45b	" " " " " " (B) "	184,950	1,238,600	4,950 (1,509)	900 (274)	6,730 (2,051)	
45c	" " " " " " (C) "	185,280	1,237,700	5,280 (1,609)	0 (0)	6,740 (2,054)	
45a	Emiss. To & Over Raw Shale Pile (A) 25 yr.	186,480	1,239,600	6,480 (1,975)	1,900 (579)	6,710 (2,045)	
45b	" " " " " " (B) "	186,870	1,240,000	6,870 (2,094)	2,300 701	6,710 (2,045)	
47a	Topsoil Dumping,Scraping,Shaping @ Raw Shale Pile 10 yr.	186,120	1,237,400	6,120 (1,865)	-300 (-91)	6,720 (2,048)	
47b	" " " " " " "	185,570	1,237,750	5,570 (1,698)	50 (15)	6,810 (2,076)	
47c	" " " " " " "	185,050	1,238,050	5,050 (1,539)	350 (107)	6,900 (2,103)	
47d	" " " " " " "	184,530	1,238,450	4,530 (1,381)	750 (229)	6,940 (2,115)	
47e	" " " " " " "	184,020	1,238,840	4,020 (1,225)	1,140 (347)	6,980 (2,128)	
47a	Topsoil Dumping,Scraping,Shaping @ Raw Shale Pile 15 yr.	185,780	1,237,280	5,780 (1,762)	-420 (-128)	6,740 (2,054)	
47b	" " " " " " "	185,640	1,237,780	5,640 (1,719)	80 (24)	6,760 (2,060)	
47c	" " " " " " "	185,500	1,238,300	5,500 (1,676)	600 (183)	6,780 (2,067)	
47d	" " " " " " "	185,320	1,238,830	5,320 (1,622)	1,130 (344)	6,800 (2,073)	
47e	" " " " " " "	185,200	1,239,370	5,200 (1,585)	1,670 (509)	6,820 (2,079)	
47f	" " " " " " "	185,020	1,239,890	5,020 (1,530)	2,190 (668)	6,840 (2,085)	

TABLE 11.7 (Concluded)
PRIMARY EMISSION SOURCE LOCATIONS AND ELEVATIONS

Source No.	Source Identification	Colorado Coordinates (N) ft.	Colorado Coordinates (E) ft.	Distance from Ref. Pt. In ft. (m) (N)	Distance from Ref. Pt. In ft. (m) (E)	Source Elevation In ft. (m)	Remarks
47a	Topsoil Dumping, Scraping, Shaping @ Raw Shale Pile 25 yr.	187,360	1,240,040	7,360 (2,243)	2,340 (713)	6,760 (2,060)	
47b	" " " " " " "	187,200	1,240,560	7,200 (2,195)	2,860 (872)	6,830 (2,082)	
49	Veh. Emiss. Over Raw Shale Pile 10 yr.	185,170	1,237,800	5,170 (1,576)	160 (49)	6,710 (2,045)	
49	" " " " " " 15 yr.	185,280	1,237,700	5,280 (1,609)	0 (0)	6,740 (2,054)	
49a	Veh. Emiss. Over Raw Shale Pile (A) 25 yr.	187,140	1,239,970	7,140 (2,176)	2,270 (692)	6,930 (2,112)	
49b	" " " " " " (B) " "	186,970	1,240,450	6,970 (2,124)	2,750 (838)	6,930 (2,112)	
50a	Topsoil Removal @ Raw Shale Area 10 yr.	185,350	1,237,280	5,350 (1,631)	-420 (-128)	6,740 (2,054)	
50b	" " " " " " " "	185,230	1,237,650	5,230 (1,594)	-50 (-15)	6,755 (2,059)	
50c	" " " " " " " "	184,680	1,238,020	4,680 (1,426)	320 (98)	6,770 (2,063)	
50d	" " " " " " " "	184,150	1,238,450	4,150 (1,265)	750 (229)	6,780 (2,067)	
50a	Topsoil Removal @ Raw Shale Area 15 yr.	185,350	1,237,820	5,350 (1,631)	120 (37)	6,700 (2,042)	
50b	" " " " " " " "	185,200	1,238,350	5,200 (1,585)	650 (198)	6,740 (2,054)	
50c	" " " " " " " "	185,010	1,238,900	5,010 (1,527)	1,200 (366)	6,780 (2,067)	
50d	" " " " " " " "	184,900	1,239,420	4,900 (1,494)	1,720 (524)	6,820 (2,079)	
50a	Topsoil Removal @ Raw Shale Area 25 yr.	186,950	1,239,700	6,950 (2,118)	2,000 (610)	6,700 (2,042)	
50b	" " " " " " " "	186,760	1,240,040	6,760 (2,060)	2,340 (713)	6,720 (2,048)	
50c	" " " " " " " "	186,830	1,240,460	6,830 (2,082)	2,760 (841)	6,750 (2,057)	

Table 11.8
SECONDARY EMISSION SOURCE LOCATIONS AND ELEVATIONS

Source No.	Source Identification	Colorado Coordinates (N) ft.	Colorado Coordinates (E) ft.	Distance from Ref. Pt. In ft. (m) (N)	Distance from Ref. Pt. In ft. (m) (E)	Source Elevation In ft. (m)	Remarks
64a	Vehicle Emission Piceance Creek Road	192,625	1,229,500	12,625 (3,848)	-8,200 (-2,499)	6,480 (1,975)	
64b	" " " " "	198,000	1,230,500	18,000 (5,486)	-7,200 (-2,195)	6,300 (1,920)	
64c	" " " " "	196,125	1,235,375	16,125 (4,915)	-2,325 (-709)	6,320 (1,926)	
64d	" " " " "	193,500	1,239,750	13,500 (4,115)	2,050 (625)	6,380 (1,945)	
64e	" " " " "	192,625	1,244,125	12,625 (3,848)	6,425 (1,958)	6,460 (1,969)	
64f	" " " " "	190,625	1,248,775	10,625 (3,239)	11,075 (3,376)	6,340 (1,932)	
64g	" " " " "	189,000	1,253,625	9,000 (2,743)	15,925 (4,854)	6,500 (1,981)	
64h	" " " " "	185,000	1,257,000	5,000 (1,524)	19,300 (5,883)	6,500 (1,981)	
64i	" " " " "	183,500	1,260,875	3,500 (1,067)	23,175 (7,064)	6,520 (1,987)	
64j	" " " " "	180,000	1,264,625	0 (0)	26,925 (8,207)	6,600 (2,012)	
64k	" " " " "	179,250	1,269,375	-750 (-229)	31,675 (9,655)	6,680 (2,036)	
64l	" " " " "	180,125	1,274,000	125 (38)	36,300 (11,064)	6,780 (2,067)	
64m	" " " " "	181,000	1,278,625	1,000 (305)	40,925 (12,474)	6,700 (2,042)	
64n	" " " " "	178,250	1,282,875	-1,750 (-533)	45,175 (13,769)	6,720 (2,048)	
64o	" " " " "	173,625	1,287,000	-6,375 (-1,943)	49,300 (15,027)	6,800 (2,073)	
64p	" " " " "	172,000	1,290,500	-8,000 (-2,438)	52,800 (16,093)	6,820 (2,079)	
64q	" " " " "	168,000	1,293,250	-12,000 (-3,658)	55,550 (16,932)	6,860 (2,091)	
64r	" " " " "	163,500	1,293,125	-16,500 (-5,029)	54,425 (16,894)	6,900 (2,103)	
64s	" " " " "	159,250	1,295,250	-20,750 (-6,325)	57,550 (17,541)	7,260 (2,213)	
64t	" " " " "	156,000	1,299,500	-24,000 (-7,315)	61,800 (18,837)	7,100 (2,164)	
64u	" " " " "	153,750	1,302,250	-26,250 (-8,001)	64,550 (19,675)	7,260 (2,213)	
64v	" " " " "	155,375	1,308,000	-24,625 (-7.506)	70,300 (21,427)	7,200 (2,195)	
64w	" " " " "	157,000	1,312,250	-23,000 (-7,010)	74,550 (22,723)	7,220 (2,201)	

Table 11.8 (Continued)
SECONDARY EMISSION SOURCE LOCATIONS AND ELEVATIONS

Source No.	Source Identification	Colorado Coordinates (N) ft.	Colorado Coordinates (E) ft.	Distance from Ref. Pt. In ft. (m) (N)	Distance from Ref. Pt. In ft. (m) (E)	Source Elevation In ft. (m)	Remarks
65	Rifle, Colorado	80,500	1,356,250	-99,500 (-30,328)	118,550 (36,134)	5,345 (1,629)	
66a	Road from Rifle to Rio Blanco Store	80,500	1,356,250	-96,250 (-29,337)	118,550 (36,134)	5,380 (1,640)	
66b	" " " " " " "	83,750	1,356,250	-91,750 (-27,965)	120,175 (36,629)	5,420 (1,652)	
66c	" " " " " " "	88,250	1,357,875	-87,000 (-26,518)	122,050 (37,201)	5,520 (1,682)	
66d	" " " " " " "	93,000	1,359,750	-81,750 (-24,917)	122,300 (37,277)	5,600 (1,707)	
66e	" " " " " " "	98,250	1,360,000	-77,000 (-23,470)	120,300 (36,667)	5,680 (1,731)	
66f	" " " " " " "	103,000	1,358,000	-74,250 (-22,631)	116,300 (35,498)	5,753 (1,754)	
66g	" " " " " " "	105,750	1,354,000	-70,500 (-21,488)	112,550 (34,305)	5,860 (1,786)	
66h	" " " " " " "	109,500	1,350,250	-67,250 (-20,498)	108,425 (33,048)	5,938 (1,810)	
66i	" " " " " " "	112,750	1,346,125	-64,750 (-19,736)	103,925 (31,676)	6,120 (1,865)	
66j	" " " " " " "	115,250	1,341,625	-61,375 (-18,707)	99,925 (30,457)	6,200 (1,890)	
66k	" " " " " " "	118,625	1,337,625	-58,500 (-17,831)	95,300 (29,047)	6,360 (1,939)	
66l	" " " " " " "	121,500	1,333,000	-54,750 (-16,688)	91,550 (27,904)	6,540 (1,993)	
66m	" " " " " " "	125,250	1,329,250	-50,500 (-15,392)	88,300 (26,914)	6,600 (2,012)	
66n	" " " " " " "	129,500	1,326,000	-46,875 (-14,288)	84,675 (25,809)	6,800 (2,073)	
66o	" " " " " " "	133,125	1,322,375	-42,875 (-13,068)	81,300 (24,780)	7,000 (2,134)	
66p	" " " " " " "	137,125	1,319.000	-38,375 (-11,697)	78,550 (23,942)	7,280 (2,219)	
66q	" " " " " " "	141,625	1,316,250	-33,500 (-10,211)	76,675 (23,371)	7,467 (2,276)	
66r	" " " " " " "	146,500	1,314,375	-28,250 (-8,611)	75,550 (23,028)	7,258 (2,212)	
66s	" " " " " " "	151,750	1,313,250	-23,125 (-7,049)	74,675 (22,761)	7,253 (2,211)	

Table 11.8 (Concluded)

SECONDARY EMISSION SOURCE LOATIONS AND ELEVATIONS

Source No.	Source Identification	Colorado Coordinates (N) ft.	Colorado Coordinates (E) ft.	Distance from Ref. Pt. In ft. (m) (N)	Distance from Ref. Pt. In ft. (m) (E)	Source Elevation In ft. (m)	Remarks
67a	Road from Rio Blanco Store to Meeker	156,875	1,312,375	-18,000 (-5,486)	74,300 (22,647)	7234 (2,206)	
67b	" " " " " " "	167,500	1,311.500	-12,500 (-3,810)	73,800 (22,494)	7360 (2,243)	
67c	" " " " " " "	172,750	1,311,625	-7,250 (-2,210)	73,925 (22,532)	7284 (2,220)	
67d	" " " " " " "	178,000	1,311,125	-2,000 (-610)	73,425 (22,380)	7200 (2,195)	
67e	" " " " " " "	183,250	1,310,500	3,250 (991)	72,800 (22,189)	7220 (2,201)	
67f	" " " " " " "	188,625	1,310,500	8,625 (2,629)	72,800 (22,189)	7220 (2,201)	
67g	" " " " " " "	194,000	1,310,625	14,000 (4,267)	72,925 (22,228)	7220 (2,201)	
67h	" " " " " " "	199,250	1,310,875	19,250 (5,867)	73,175 (22,304)	7230 (2,204)	
67i	" " " " " " "	204,500	1,311,000	24,500 (7,468)	73,300 (22,342)	7210 (2,198)	
67j	" " " " " " "	209,875	1,310,875	29,875 (9,106)	73,175 (22,304)	7260 (2,213)	
67k	" " " " " " "	215,125	1,310,750	35,125 (10,706)	73,050 (22,266)	7000 (2,134)	
67l	" " " " " " "	220,125	1,309,500	40,125 (12,230)	71,800 (21,885)	6980 (2,128)	
67m	" " " " " " "	225,000	1,309,625	45,000 (13,716)	71,925 (21,923)	6791 (2,070)	
67n	" " " " " " "	230,250	1,308,625	50,250 (15,316)	70,925 (21,618)	6740 (2,054)	
67o	" " " " " " "	235,125	1,308,000	55,125 (16,802)	70,300 (21,427)	6610 (2,015)	
67p	" " " " " " "	240,125	1,308,375	60,125 (18,326)	70,675 (21,542)	6532 (1,991)	
67q	" " " " " " "	245,125	1,308,875	65,125 (19,850)	71,175 (21,694)	6520 (1,987)	
67r	" " " " " " "	250,125	1,308,875	70,125 (21,374)	71,175 (21,694)	6480 (1,975)	
67s	" " " " " " "	255,500	1,308,625	75,500 (23,012)	70,925 (21,618)	6200 (1,890)	
67t	" " " " " " "	260,000	1,310,875	80,000 (24,384)	73,175 (22,304)	6180 (1,884)	
67u	" " " " " " "	261,000	1,316,000	81,000 (24,689)	78,300 (23,866)	6200 (1,890)	
67v	" " " " " " "	264,500	1,319,875	84,500 (25,756)	82,175 (25,047)	6240 (1,902)	
67w	" " " " " " "	266,250	1,324,000	86,250 (26,289)	86,300 (26,304)	6239 (1,902)	
68	Meeker, Colorado	266,250	1,324,000	86,250 (26,289)	86,300 (26,304)	6239 (1,902)	

TABLE 11.9a

Wind Persistence at Specified Stability
Stability A
November 1974 - October 1976
Stability Determined from 200'-30' on Meteorological Tower Corrected for Wind Speed

Direction	Persistence as Duration (Speed)/Date*		
	1	2	3
N	2 (1.5) / 6-5-75		
NNE	4 (2.) / 12-24-75		
NE	2 (2.) / 12-8-75	2 (2.5) / 4-3-76	2 (2.5) / 10-1-76
ENE	2 (3.) / 9-8-75	2 (1.5) / 5-23-76	2 (2.) / 7-13-76
E	2 (2.5) / 11-15-75	2 (2.5) / 7-24-76	
ESE			
SE	2 (4.) / 5-21-75		
SSE			
S			
SSW	2 (4.) / 12-5-75	2 (5.5) / 5-8-76	
SW	3 (2.2) / 5-8-76	2 (1.5) / 9-20-76	
WSW	2 (1.5) / 8-1-76		
W	4 (3.8) / 2-5-76	3 (3.3) / 4-12-75	3 (3.0) / 2-6-76
WNW	6 (2.7) / 10-27-75		
NW	3 (2.) / 10-24-75	4 (2.5) / 3-7-76	
NNW	3 (2.) / 11-8-75		

*Duration in Hours and Wind Speed at 30 Ft in MPH.

TABLE 11.9b
(Continued)

WIND PERSISTENCE AT SPECIFIED STABILITY
STABILITY B
NOVEMBER 1974 - OCTOBER 1976
STABILITY DETERMINED FROM 200'-30' ON
METEOROLOGICAL TOWER CORRECTED FOR WIND SPEED

DIRECTION	PERSISTENCE AS DURATION (SPEED)/DATE*		
	1	2	3
N	4 (6.) / 9-28-76		
NNE	2 (7.) / 9-27-75	3 (4.7) / 10-17-75	
NE	4 (9.5) / 7-23-76		
ENE	2(3.5) / 8-20-75	2 (4.) / 10-25-75	
E	4 (4.5) / 7-31-76		
ESE	2 (8.) / 5-21-75		
SE			
SSE	3(6.) / 12-6-75	2 (7.) / 10-26-75	
S	6(7.8) / 3-31-76	5 (5.8) / 12-4-75	
SSW	6 (8.5) / 2-11-76	5 (7.4) / 3-16-76	4 (8.) / 8-5-75
SW	7 (9.3) / 10-18-75	5 (11.6) / 1-18-76	
WSW	4 (7.3) / 6-11-75		
W	3 (8.3) / 4-27-75	4 (6.5) / 4-29-75	
WNW	5 (7.6) / 5-2-75		
NW	7 (10.9) / 12-14-75		
NNW	6 (9.3) / 5-31-75		

*DURATION IN HOURS AND WIND SPEED AT 30 FT IN MPH.

TABLE 11.9c
(Continued)

WIND PERSISTENCE AT SPECIFIED STABILITY
STABILITY C
NOVEMBER 1974 - OCTOBER 1976
STABILITY DETERMINED FROM 200'-30' ON
METEOROLOGICAL TOWER CORRECTED FOR WIND SPEED

DIRECTION	PERSISTENCE AS DURATION (SPEED)/DATE*		
	1	2	3
N	3 (14.) / 4-30-76	3 (12.) / 9-26-76	
NNE	2 (12.5) / 9-30-75		
NE	2 (10.) / 6-16-76		
ENE			
E			
ESE			
SE			
SSE	2 (13.5) / 4-25-76	2 (12.0) / 7-19-76	
S	2 (12.0) / 3-11-76		
SSW	4 (12.8) / 3-18-75	4 (12.3) / 5-15-75	4 (13.8) / 3-13-76
SW	3 (12.3) / 4-9-75	3 (12.3) / 5-18-76	3 (9.7) / 6-12-76
WSW	2 (12.) / 8-23-76		
W	2 (11.5) / 6-24-76		
WNW	3 (8.) / 1-1-76	2 (3.) / 4-11-75	2 (12.5) / 11-29-75
NW	8 (6.5) / 10-23-75	4 (13.5) / 11-18/19-75	
NNW	2 (11.5) / 5-29-75		

*DURATION IN HOURS AND WIND SPEED AT 30 FT IN MPH.

Wind Persistence at Specified Stability

Stability D

November 1974 - October 1976

Stability Determined from 200′-30′ on Meteorological Tower Corrected for Wind Speed

Direction	Persistence as Duration (Speed)/Date*		
	1	2	3
N	6 (14.5) / 4-30-76		
NNE	4 (3.5) / 4-26-75		
NE			
ENE			
E	2 (2.5) / 8-21-75	2 (5.) / 10-14-75	
ESE	2 (17.5) / 7-20-76		
SE	5 (13.8) / 7-23-76	2 (2.) / 3-23-75	2 (17.5) / 7-9-76
SSE	2 (18.) / 3-25-76	3 (13.) / 10-10-75	
S	12 (38.3) / 4-25-75	11 (18.5) / 3-25-75	11 (19.) / 10-11/12-75
SSW	25 (21.) / 2-7-75	25 (27.3) / 10-26-75	15 (22.2) / 12-1-75
SW	10 (15.4) / 4-22-75	9 (20.3) / 8-23-75	
WSW	5 (18.) / 4-9-76	3 (10.) / 4-18-75; 3 (16.7) / 5-15-75	3 (15.3) / 11-6-75
W	4 (18.3) / 1-25-75		
WNW	6 (21.2) / 3-19-76	5 (13.4) / 1-7-75	5 (4.) / 2/15/75; 5 (19.) / 2-18-76
NW	6 (7.5) / 1-8/9-75	4 (4.8) / 4-25-75	
NNW	4 (13.8) / 1-21-75		

*Duration in Hours and Wind Speed at 30 Ft in MPH.

WIND PERSISTENCE AT SPECIFIED STABILITY
STABILITY E
NOVEMBER 1974 - OCTOBER 1976
STABILITY DETERMINED FROM 200'-30' ON METEOROLOGICAL TOWER CORRECTED FOR WIND SPEED

DIRECTION	PERSISTENCE AS DURATION (SPEED)/DATE*		
	1	2	3
N	2 (11.)/9-20-75	2 (6.)/9-30-75	
NNE	2 (10.)/9-20-75	2 (3.)/6-24-76	
NE	2 (2.)/1-22-75		
ENE			
E	2 (7.)/11-17-75	4 (4.8)/11-11/12-75	
ESE	3 (7.7)/8-9-76	3 (2.7)/9-18-76	3 (8.)/6-29/30-76
SE	4 (6.3)/8-27-75	4 (3.3)/9-1-75	3 (10.)/7-11-76
SSE	4 (7.)/8-27-75	4 (13.3)/10-6-75	
S	4 (11.7)/4-15-75	4 (11.3)/4-24-75 4(11.3)/10-11-75	4 (14.)/8-7-76
SSW	7 (13.2)/2-11-75	7(8.6)/5-23-75	6(2.2)/2-16-75 6(13.8)/9-1-75
SW	6 (12.5)/4-13-75	5 (9.)/1-16-75	
WSW			
W	10 (4.7)/9-19/20-76	5 (6.)/4-12/13-75	4 (3.3)/2-14-75
WNW	3 (6.7)/2-14-75		
NW	3 (6.3)/2-15-75		
NNW	5 (8.)/1-9-75		

*DURATION IN HOURS AND WIND SPEED AT 30 FT IN MPH.

Wind Persistence at Specified Stability
Stability F
November 1974 - October 1976
Stability Determined from 200'-30' on Meteorological Tower Corrected for Wind Speed

Direction	Persistence as Duration (Speed)/Date*		
	1	2	3
N	2 (3.) 6-7-75	2 (.5) 11-6-75	
NNE		2 (.5) 9-22-75	
NE	3 (1.) 8-30-75	2 (2.) 8-9-75	2 (1.5) 8-10-75
ENE	2 (2.5) 8-29-75		
E	3 (1.7) 8-3-75	2 (2.5) 8-30-76	
ESE	3 (2.3) 8-3-75	3 (6.5) 9-5-75	
SE	6 (5.8) 2-23-76	5 (3.0) 10-1-76	
SSE	4 (3.3) (1) 12-3-75		
S	5 (4.2) 1-19-75	4 (3.) 6-1/2-76	4 (7.5) (2) 10-6-75
SSW	6 (2.) (3) 6-5-75	5 (5.6) 10-5-75	6 (11.3) 5-28/29-76
SW	3 (4.7) 1-23-75		
WSW			
W	2 (2.5) 8-8-75	2 (3.) 6-27-76	
WNW	3 (6.) 9-17-75	3 (3.3) 9-21-75	
NW	2 (3.5) 1-1-75	2 (5.5) 9-29-75	
NNW	2 (3.) 1-1-75	2 (2.) 9-29-75	

(1) The wind pattern of SE-SE-SSE-SSE SSE-SE-SSE was credited as 4 hrs at SSE and 3 hrs at SE.

(2) The wind pattern of S-S-S-SSE-SSE SSE-S was credited as 3 hrs at SSE and 4 hrs at S.

(3) The wind pattern of SSW-SSW-S-S-S-SSW SSW-SSW-SSW was credited as 6 hrs at SSW and 3 hrs at S.

*Duration in Hours and Wind Speed at 30 Ft in MPH.

TABLE 11.10

WIND SPEED ADJUSTMENTS* TO PASQUILL-GIFFORD

STABILITY CLASSES OBTAINED FROM METEOROLOGICAL

ΔT DATA

Stability from ΔT	Wind Speed (WS) (m/s)	"Adjusted Stability"
A	WS <2.0	A
	$2.0 \leq$ WS ≤ 5.0	B
	$5.0 \leq$ WS ≤ 6.0	C
	WS >6.0	D
B	WS <5.0	B
	$5.0 \leq$ WS ≤ 6.0	C
	WS >6.0	D
C	WS ≤ 5.0	C
	WS >5.0	D
D	ALL SPEEDS	D
E	WS ≤ 5.0	E
	WS ≥ 5.0	D
F	WS <3.0	F
	$3.0 \leq$ WS ≤ 5.0	E
	WS ≥ 5.0	D

* Provided by the EPA

TABLE 11.11a Bivariate Wind Frequency Distributions by Stability Class

STABILITY CLASS DETERMINED BY TEMPERATURE LAPSE RATE
200-FOOT LEVEL PERIOD(3/ 1/75 TO 2/28/76)

STABILITY CLASS - A

		WIND DIRECTION																
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL	%
GROUP MAX SPEED MPH		9.	9.	7.	8.	9.	9.	8.	9.	9.	13.	10.	9.	12.	10.	9.	8.		
GT 21	:																	:	0.
16 - 21	:																	:	0.
13 - 16	:										3	4		1	1			: 9	0.
6 - 10	:	12	15	18	10	13	16	21	42	56	105	64	49	62	113	71	38	: 703	11.
3 - 5	:	279	245	207	143	156	168	132	97	138	148	153	168	325	523	416	271	: 3561	53.
LT 3	:	200	215	162	161	122	143	93	76	87	72	92	114	187	264	243	182	: 2413	36.
TOTAL	:	491	475	385	314	291	327	246	215	281	328	313	331	575	901	730	491	/ 6686	
PERCENT	:	7.	7.	6.	5.	4.	5.	4.	3.	4.	5.	5.	5.	9.	13.	11.	7.	:	100.

TOTAL NUMBER OF CALMS DISTRIBUTED ABOVE - 454(6.79 %)

TABLE 11.11b Bivariate Wind Frequency Distributions by Stability Class

STABILITY CLASS DETERMINED BY TEMPERATURE LAPSE RATE
200-FOOT LEVEL PERIOD(3/ 1/75 TO 2/28/76)

STABILITY CLASS - B

GROUP MAX SPEED MPH		WIND DIRECTION N 18.	NNE 17.	NE 13.	ENE 19.	E 14.	ESE 16.	SE 15.	SSE 18.	S 20.	SSW 20.	SW 18.	WSW 17.	W 18.	WNW 16.	NW 18.	NNW 17.		TOTAL	%
GT 21	:																	:		0.
16 - 21	:	6	2		1		1		7	28	107	33	6	4	4	16	8	:	223	2.
10 - 16	:	200	106	54	44	56	71	68	177	571	1399	1074	334	260	586	899	414	:	6313	44.
6 - 10	:	297	174	132	103	91	121	166	218	351	557	433	348	421	985	994	500	:	5851	41.
3 - 6	:	117	83	63	66	65	61	55	44	45	81	51	45	165	371	207	122	:	1638	11.
LT 3	:	24	22	29	24	16	14	7	12	15	19	18	18	28	36	35	21	:	339	2.
TOTAL	:	644	384	276	238	228	268	296	458	1011	2163	1609	711	878	1982	2151	1065	:	14364	
PERCENT	:	4.	3.	2.	2.	2.	2.	2.	3.	7.	15.	11.	5.	6.	14.	15.	7.	:		100.

TOTAL NUMBER OF CALMS DISTRIBUTED ABOVE - 62(0.43 %)

TABLE 11.11c Bivariate Wind Frequency Distributions by Stability Class

STABILITY CLASS DETERMINED BY TEMPERATURE LAPSE RATE
200-FOOT LEVEL PERIOD(3/ 1/75 TO 2/28/76)

STABILITY CLASS - C

GROUP MAX SPEED MPH		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW		TOTAL	%
		21.	18.	15.	16.	15.	16.	17.	26.	21.	24.	23.	19.	19.	19.	23.	21.			
GT 21	:	1								9	20	2				1	1	:	34	1.
16 - 21	:	10	12		3		2	5	29	97	428	221	72	42	42	111	73	:	1139	25.
10 - 16	:	55	49	16	13	15	9	25	52	172	554	422	133	110	195	311	112	:	2243	48.
6 - 10	:	23	10	2	5	12	10	22	26	43	55	25	21	30	58	94	27	:	461	10.
3 - 6	:	18	14	22	15	29	18	10	22	29	49	44	25	39	74	39	24	:	465	10.
LT 3	:	14	18	17	10	15	21	10	13	16	24	17	24	22	28	29	20	:	298	6.
TOTAL	:	121	123	55	46	71	60	78	142	366	1122	727	275	243	397	585	257	:	4640	
PERCENT	:	3.	2.	1.	1.	2.	1.	2.	3.	8.	24.	16.	6.	5.	9.	13.	6.	:		100.

TOTAL NUMBER OF CALMS DISTRIBUTED ABOVE - 64(1.38 %)

TABLE 11.11d Bivariate Wind Frequency Distributions by Stability Class

STABILITY CLASS DETERMINED BY TEMPERATURE LAPSE RATE
200-FOOT LEVEL PERIOD(3/ 1/75 TO 2/28/76)

STABILITY CLASS - D

GROUP MAX SPEED MPH		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW		TOTAL	%
		28.	28.	28.	25.	26.	27.	24.	42.	56.	52.	57.	39.	34.	32.	39.	30.			
GT 21	:	42	13	9	5	6	9	3	149	1776	3036	1357	211	97	179	178	95	:	7157	38.
16 - 21	:	76	41	8	7	7	13	53	191	727	1469	909	237	150	264	331	135	:	4598	24.
13 - 16	:	46	52	14	5	14	38	61	175	335	453	191	92	67	121	174	64	:	1932	10.
6 - 13	:	85	41	32	28	37	79	99	134	183	228	86	96	145	194	175	96	:	1789	9.
3 - 6	:	69	64	57	71	81	97	102	149	137	167	185	151	212	165	114	55	:	1836	10.
LT 3	:	89	59	87	81	103	101	77	109	102	114	108	100	125	131	132	113	:	1631	9.
TOTAL	:	387	270	287	195	248	320	395	867	3244	5467	2838	887	796	1054	1096	558	:	18833	
PERCENT	:	2.	1.	1.	1.	1.	2.	2.	5.	17.	29.	15.	5.	4.	6.	6.	3.	:		100.

TOTAL NUMBER OF CALMS DISTRIBUTED ABOVE - 356(1.89 %)

TABLE 11.11e Bivariate Wind Frequency Distributions by Stability Class

STABILITY CLASS DETERMINED BY TEMPERATURE LAPSE RATE
200-FOOT LEVEL PERIOD(3/ 1/75 TO 2/28/76)

STABILITY CLASS - E

GROUP MAX SPEED MPH		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW		TOTAL	%
		18.	16.	20.	19.	15.	17.	18.	20.	23.	23.	21.	20.	21.	17.	18.	19.			
GT 21	:									9	52	2		1				:	64	1.
16 - 21	:	9	3	4	2		1	25	72	173	329	132	13	16	1	19	8	:	807	7.
13 - 16	:	53	35	7	7	18	45	131	283	375	602	301	67	22	55	98	56	:	2145	18.
8 - 13	:	49	34	24	49	65	155	312	307	346	427	214	130	205	151	66	52	:	2598	22.
3 - 8	:	64	51	78	75	126	283	345	283	388	409	251	218	186	181	92	72	:	3814	26.
LT 3	:	73	105	198	162	187	248	285	234	244	262	238	197	204	166	137	99	:	3023	26.
TOTAL	:	245	228	295	295	395	732	1098	1179	1458	2081	1130	625	634	554	494	287	:	11641	
PERCENT	:	2.	2.	3.	3.	3.	6.	9.	10.	13.	18.	10.	5.	5.	5.	3.	2.	:		100.

TOTAL NUMBER OF CALMS DISTRIBUTED ABOVE - 726(6.24 %)

TABLE 11.11f Bivariate Wind Frequency Distributions by Stability Class

STABILITY CLASS DETERMINED BY TEMPERATURE LAPSE RATE
200-FOOT LEVEL PERIOD(3/ 1/75 TO 2/28/76)

STABILITY CLASS - F

GROUP MAX SPEED MPH		WIND DIRECTION N 12.	NNE 11.	NE 8.	ENE 9.	E 12.	ESE 11.	SE 15.	SSE 15.	S 19.	SSW 17.	SW 17.	WSW 15.	W 13.	WNW 12.	NW 15.	NNW 12.		TOTAL	%
GT 21	:																	:		0.
16 - 21	:									26	11	5						:	42	0.
10 - 16	:	5	4			5	8	28	38	112	216	109	25	12	3	5	1	:	572	6.
6 - 10	:	4	8	4	5	29	129	223	221	236	303	146	78	42	52	28	17	:	1529	17.
3 - 6	:	40	42	42	58	167	357	441	375	421	348	213	200	125	83	83	42	:	3037	34.
LT 3	:	146	179	185	212	316	346	393	343	365	294	234	187	181	175	187	148	:	3889	43.
TOTAL	:	195	233	232	275	517	848	1085	977	1160	1172	703	490	368	314	384	248	:	9065	
PERCENT	:	2.	3.	3.	3.	6.	9.	12.	11.	13.	13.	8.	5.	4.	3.	3.	2.	:		100.

TOTAL NUMBER OF CALMS DISTRIBUTED ABOVE - 919(10.14 %)

TABLE 11.11g Bivariate Wind Frequency Distributions by Stability Class

STABILITY CLASS DETERMINED BY TEMPERATURE LAPSE RATE
200-FOOT LEVEL PERIOD(3/ 1/75 TO 2/28/76)

STABILITY CLASS - TOTAL

GROUP MAX SPEED MPH		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW		TOTAL	%
		28.	24.	26.	25.	26.	27.	24.	42.	56.	52.	57.	39.	34.	32.	39.	30.			
GT 21	:	43	13	9	5	6	9	3	149	1794	3128	1361	211	98	179	171	96	:	7255	11.
16 - 21	:	101	58	12	13	7	17	83	299	1031	2336	1300	328	212	311	477	224	:	6889	10.
10 - 16	:	356	246	91	69	108	171	313	725	1566	3227	2101	651	472	951	1480	647	:	13184	20.
6 - 10	:	450	282	210	198	247	501	941	948	1217	1675	973	602	905	1553	1428	738	:	12037	20.
3 - 6	:	587	496	459	428	624	984	1095	930	1078	1194	993	827	1052	1397	951	586	:	13551	21.
LT 3	:	566	613	679	656	755	857	840	765	806	768	687	636	764	846	792	601	:	11633	18.
TOTAL	:	2103	1708	1460	1369	1747	2539	3165	3816	7494	12308	7312	3315	3503	5247	5299	2884	:	65269	
PERCENT	:	3.	3.	2.	2.	3.	4.	5.	6.	11.	19.	11.	5.	5.	8.	8.	4.	:		100.

(Column heading WIND DIRECTION spans N through NNW.)

TOTAL NUMBER OF CALMS DISTRIBUTED ABOVE - 2581(3.95 %)

PERCENTAGE OF A STABILITY - 12.24 %
PERCENTAGE OF B STABILITY - 22.01 %
PERCENTAGE OF C STABILITY - 7.11 %
PERCENTAGE OF D STABILITY - 28.85 %
PERCENTAGE OF E STABILITY - 17.84 %
PERCENTAGE OF F STABILITY - 13.89 %

TABLE 11.12

Upper-Air Stability Classes (Pibal Data)

November 77-November 78

Height (m)	Stability Class	Morning Frequency					Afternoon Frequency				
		Winter	Spring	Summer	Fall	Year	Winter	Spring	Summer	Fall	Year
150	A	0	0	0	0	0	0	0	13.6	18.2	9.7
	B	4.8	0	0	0	1.2	0	0	4.5	4.5	2.8
	C	0	0	0	0	0	7.1	0	0	13.6	5.6
	D	42.9	14.3	3.7	19.0	19.3	71.4	92.9	77.3	40.9	68.1
	E	52.4	64.3	63.0	38.1	54.2	21.4	7.1	4.5	18.2	12.5
	F	0	21.4	33.3	42.9	25.3	0	0	0	4.5	1.4
300	A	3.7	0	0	0	0.8	0	6.1	6.5	5.4	4.8
	B	0	0	0	0	0	0	3.0	0	2.7	1.6
	C	3.7	0	0	0	0.8	0	0	6.5	5.4	3.2
	D	55.6	30.0	18.2	28.6	31.9	66.7	72.7	71.0	59.5	67.2
	E	37.0	70.0	75.8	72.4	64.7	33.3	18.2	16.1	27.0	23.2
	F	0	0	6.1	0	1.9	0	0	0	0	0
500	A	0	3.6	3.1	0	1.7	0	3.1	6.5	0	2.5
	B	0	0	0	0	0	0	0	3.2	0	0.8
	C	0	0	0	0	0	0	3.1	3.2	0	1.7
	D	44.8	35.7	34.4	32.3	36.7	72.7	75.0	64.5	66.7	69.4
	E	55.2	53.6	62.5	67.7	60.0	27.3	18.8	22.6	30.6	24.8
	F	0	7.1	0	0	1.7	0	0	0	2.8	0.8
1000	A	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	4.0	0.9	0	7.4	0	0	2.0
	C	0	0	0	0	0	0	0	6.9	9.4	4.9
	D	45.5	77.8	56.3	48.0	57.5	64.3	85.2	79.3	62.5	73.5
	E	50.0	22.2	43.7	48.0	40.6	35.7	7.4	13.8	28.1	19.6
	F	4.5	0	0	0	0.0	0	0	0	0	0

12.0

APPENDIX 12.0

Conditional Prevention of Significant Deterioration
Permit, C-b
- Ancillary Phase -

Conditional Permit to Commence Construction and Operate
Prevention of Significant Deterioration of Air Quality
Review of New Sources

C-b Shale Oil Venture

Rio Blanco County, Colorado

I. INTRODUCTION

The C-b Shale Oil Venture Project (C-b) consisting of Occidental Oil Shale, Inc., and Ashland Oil of Colorado plans to construct and operate a modified in-situ oil shale resource development project. This conditional permit covers only the first phase of operations which may lead to commercial phase operation. This phase as described in the C-b application covers the site preparation, shaft sinking, and retorting of the ancillary phase of the project which extends over a time period from the date of issuance of this permit until about 1982. Specific activities covered by this conditional permit include general site preparation, the sinking of four shafts, and the operation of a two retort module and a four retort module-the larger of which is designed to produce about 5,000 barrels a day. Other on-site support facilities will be constructed along with the above.

On October 4, 1977 the U.S. Environmental Protection Agency, Region VIII EPA determined that "the collaring of the proposed first ancillary phase shaft" was determined to be commencement of construction. Pursuant to the requirements of 40 CFR 52.21(d) and Title I Part C of the Clean Air Act Amendments of 1977 (42 USC 7401 et. seq.), a source may not commence construction prior to receiving this EPA approval. Subsequently, requests were made by C-b to reverse our decision but it has been determined that the above definition of commencement of construction is appropriate. Correspondence and information related to this determination is cited in Appendix 1. On Oceober 17, 1977 C-b pursuant to the above determination filed a complete application requesting EPA permission to construct and operate the ancillary phase of their oil shale facility. Subsequently clarifying information for the permit application was provided on October 26 and October 31, 1977.

On the basis of the information submitted by C-b, EPA made a preliminary determination that a conditional PSD permit should be granted. EPA notified the appropriate Federal Land Manager and Federal Officials charged with the responsibility of protecting the air resources of Class I areas in the vicinity of the operation. A notice of a public hearing to be held in Rifle, Colorado on December 6, 1977, was published in local and state newspapers. The hearing was held on December 6. A summary of the hearing testimony and written submissions is part of the analyses indicated in Appendix 3. Comments received during the public hearing and via written submissions to EPA have been fully considered by EPA in its final determination.

II. FINDINGS

Information considered and used by EPA in its review of the C-b permit application is listed in Appendix 2. On the basis of that information EPA has determined that:

A. C-b proposes the application of best available control technology (BACT), as defined in 40 CFR 52.21 and 42 USC 7401 et. seq., and will limit emissions from the facility as set forth in III(B) below;

B. The emission limitations will insure that the applicable PSD air quality increments will not be violated;

C. Violations of the national ambient air quality standards will not be caused or exacerbated by the facility;

D. The ambient and the emissions monitoring program as described in the C-b application coupled with the conditions to this permit will adequately assess the air quality impacts from this facility and ensure continued compliance with the terms and conditions of this permit.

E. EPA has good reason to believe that C-b can comply with the conditions of this permit. However, in the issuance of this permit neither EPA nor its findings assume any risk of loss which may occur as a result of the commencement of construction and operation by C-b if conditions of this permit are not met by C-b.

These findings are based upon the analyses listed in Appendix 3. On the basis of currently available engineering, design, and operating data EPA has no reason to doubt C-b's representation that emissions from the source will remain within the allowable limits. However, in view of the limited amount and nature of data on air emissions from operating in-situ oil shale facilities and the tentative nature of actual design specifications of air pollution control equipment this conditional permit to construct and operate (III below) is expressly conditioned upon the continuing validity of C-b's representations in their application and their good faith best efforts to ensure that actual design specifications and process operations are such as to ensure compliance with this conditional permit. Also, it is recognized that due to the prototype nature of the technology of oil shale development there may exist a need to revise the permit at some time during its operable life.

III. CONDITIONAL PERMIT TO CONSTRUCT AND OPERATE

On the basis of the findings set forth in II above and pursuant to the authority (as delegated by the Administrator) of 40 CFR 52.21(d)(2) and 42 USC 7401 et. seq. EPA hereby grants conditional approval to C-b to commence

construction and operate its proposed modified in-situ oil shale operation and related facilities on a federal lease tract about 20 miles west of Rio Blanco, Colorado. This approval is expressly conditioned as follows:

A. C-b shall submit to EPA within 20 working days after it becomes available, copies of all engineering design and technical data pertaining to the selected control devices, (e.g., Stretford Plant, baghouses, dust palliatives, etc.) in order for EPA to verify the likelihood of the control device to achieve the emission limits stated below. EPA may upon review of these data deem this conditional permit void if EPA determines the control methods to be inadequate to meet the emission limits specified in this conditional approval. Final plans or specifications on control devices shall include at a minimum a description of the systems operation, major design parameters, and efficiency guarantees. Such information should be accompanied by one copy of all pertinent air pollution control aspects of all contracts, purchase orders, and vendor proposals which C-b plans for the purpose of construction of the control device. Should EPA determine that C-b's final plans contain insufficient or inaccurate information to sustain this permit or if EPA makes a preliminary determination that the control methods are inadequate to meet the emission limits in III(B) EPA shall so notify C-b within 30 days of EPA's receipt of such plans. C-b shall have 30 days after notice to submit complete design, engineering and operating data. EPA shall make a final determination on the adequacy of the information and/or control methods within 30 days of receipt of such information. If EPA determines that the control methods are inadequate to achieve the emission limits in III(B) above or any other condition of this permit, or if information required to make a determination is still inadequate EPA may declare this conditional permit void upon written notice to C-b until the condition or conditions in question are satisfied. Such final agency action shall be effective immediately upon C-b's receipt of such written notice. Construction or operation of the source during any period in which the permit is deemed void is expressly prohibited until the permit is reinstated in writing by EPA. Failure of EPA to take action pursuant to this condition shall not constitute a guarantee that the control devices will in fact enable C-b to meet the conditions of this permit.

B. C-b shall limit emissions from the facility as shown in the table below.

C-b Emissions Summary, Pounds per hour

Ancillary Development

	TSP	SO_2
a. Mine vent	16.0	7.0
b. In-situ gas	7.4	17.4
c. Steam boiler	16.3	3.6
d. Storage tank	-	-
e. Mine shaft transfer	1.7	-
f. Shale conveyor	7.7	-
g. ROM ore handling	29.2	-
TOTAL	78.3	28.0
(Annual tpy)	(343)	(123)

C. The sulfur removal facility for control of gaseous sulfur emissions from the facility shall be designed and operated in order to insure at least 99.0% over-all gaseous sulfur recovery and no greater than 15 parts per million H_2S concentration in the off gas are continuously achieved. Also, emissions from the power generation facilities shall not exceed 0.1 pounds per million BTU of particulate matter and 0.8 pounds per million BTU of SO_2 or the emissions limits as stated in the table above whichever is less as measured by the procedures set forth in 40 CFR 60.46.

D. Particulate emissions emanating from the underground mining activity and from the above ground mine shaft transfer of mined cut shale shall be continuously controlled such that the emissions limits in III(B) are met. At no time shall visible emissions exceed 20% opacity.

E. Fugitive dust control measures including watering and/or chemical dust suppressants shall be used to minimize to the greatest extent practicable the amount of fugitive dust emanating from disturbed areas as described in C-b's permit application including but not limited to haul roads, access roads, parking areas, drill pads, and shale disposal areas. Disposal of the run of mine ore shall be performed in a manner which involves compaction and rapid revegetation of the disposed material. A maximum of 80 acres of this disposed shale material shall remain in an active working disposal state at any given time.

F. A performance test of the sulfur removal facility shall be conducted pursuant to the provisions of 40 CFR 60.7, 60.8 and EPA Method 11 or equivalent. Performance tests of the steam boilers shall be conducted pursuant to the provisions of 40 CFR 60.7, 60.8, 60.46 and EPA Methods 5, 6 and 7. Periodic performance tests of particulate emissions emanating from the mine vent shall be conducted pursuant to provisions of 40 CFR 60.8 and EPA Method 5. Periodic tests to determine the particle size distribution and chemical composition of particulates in the in-situ gas stream shall be conducted.

G. Should any of the tests indicated in III above indicate that the source has not met the emissions limitations set forth in III(B) above or any other condition herein, this conditional permit to construct and operate shall upon written notification of C-b by EPA be deemed void. EPA shall notify C-b in writing of its determination if conditions of the permit have not been met and that the permit is deemed void. Construction or operation of the source during is deemed void is expressly prohibited until the permit is reinstated in writing by EPA. Performance test results which exceed the emission limits of III(B) above shall constitute prima facie evidence in any proceeding to enforce the terms of this permit that the emissions from the source exceed these limits.

H. Except as modified in condition III(O) - C-b shall install, calibrate, maintain, and operate emission and monitoring devices and make periodic reports according to Region VIII instructions (see attached) as required by 40 CFR 60.7, 60.13 and 60.45 on the steam boiler.

Also, C-b shall install, calibrate, maintain, and operate emission monitoring devices and make periodic reports for gaseous sulfur concentrations (including H_2S, SO_2, CS_2, COS, RSH, etc.) and gas quantities pursuant to the provisions of 40 CFR 60.7, 60.8 and EPA Methods 2 and 11 at the inlet and outlet of the sulfur removal facility in order to evaluate the control efficiency of the sulfur removal facility on a daily basis. Also, C-b shall operate monitoring devices or methods which will provide data in order to make the determination that other conditions of the permit are met.

The following definitions of excess emissions supercede the provisions of 40 CFR 60.45(g).

(1) Opacity - excess emissions are defined as any 6 minute period in which the average opacity of emissions exceeds 20% opacity; except that one 6 minute period per hour of not more than 27% opacity need not be reported.

(2) H_2S - excess emissions are defined as any daily period in which the average control efficiency of the sulfur removal facility is less than 99.0 percent overall sulfur recovery, the H_2S average concentration exceeds 15 parts per million volume on a dry basis at zero percent oxygen, and/or the emissions exceed those limits in III-B above.

(3) Excess emissions of particulate and sulfur dioxide from the mine vent are defined as any emissions which taken on a daily average exceed the emission limits in III(B) above.

I. C-b shall comply with all notification and record keeping requirements of 40 CFR 60.7. C-b shall provide written monthly summaries of the sulfur removal facility inlet and outlet gaseous sulfur concentrations (daily averages) within 30 days of the last day of the calendar month, during the period of retort burns (estimated to occur during separate 9 month periods during 1981 and 1982).

J. C-b shall maintain records of the amount of water used and/or dust palliative used for purposes of fugitive dust control on a monthly basis for a period of at least 2 years. Quarterly submittals of written summaries shall be provided to EPA within 30 days of the last day of the quarter.

K. C-b shall for each petroleum storage vessel subject to 40 CFR 60 Subpart K determine and record the average monthly storage temperature and vapor pressure of the petroleum liquid stored. C-b shall maintain records of this information for a period of at least 2 years.

L. Tonnage of material removed via shaft collaring, sinking and underground retort preparation shall be estimated and recorded on a monthly basis by C-b. The amount of blasting powder used and the blasting frequency shall be recorded on a monthly basis. Finally an estimate of the amount of diesel fuel and gasoline usage shall be made on a monthly basis by C-b. All information in this part III-(L) shall be recorded and maintained by C-b for a period of two years. Quarterly submittals to EPA shall be made within 30 days of the last day of the calendar quarter.

M. No condition herein shall excuse the C-b Shale Oil Venture from complying with all state or local air pollution control requirements; with air quality provisions of the detailed development plan approved by the USGS Area Oil Shale Supervisor; or of any other Federal, State or local air quality regulations. Failure of EPA to take action pursuant to the terms of this permit shall not constitute a waiver of any of the conditions herein.

N. EPA will entertain any written application at any time or times from C-b for a modification or adjustment of any emission limit or other condition imposed by this permit. The application shall (1) specify each limit or condition for which modification or adjustment is sought;

(2) provide specific details on the extent and nature of the modification sought; (3) provide specific data regarding why the modification is considered necessary; (4) provide information necessary to determine the environmental impact associated with such modification; and (5) furnish any other information deemed necessary by EPA in order to demonstrate that the intent of the PSD provisions, i.e., attainment of increments, NAAQS, BACT, etc., will continue to be satisfied. EPA shall make a preliminary determination regarding the modification or adjustment sought within 30 days of EPA's receipt of such application. EPA shall provide written notice of its findings and action at the time of its determination.

O. Reporting requirements of excess emissions during periods of startup, shutdown, equipment malfunction and/or process upset are as follows. Notification by C-b to the EPA within 48 hours of discovery of upset conditions shall be provided. Within 10 days of discovery all of the following shall be provided to EPA by C-b:

1. The identity of the stack or other emission points where excess emissions occurred;

2. The magnitude of excess emissions expressed in terms of the permit conditions;

3. Pertinent operating data during the time of upset;

4. The time and duration of excess emissions;

5. The identity of the equipment and/or process causing the upset and the suspected reasons for the upset;

6. Steps and procedures taken during the upset period to minimize excess emissions; and

7. Steps and procedures taken or anticipated to be taken to prevent reoccurence of the upset conditions.

Information reported under this condition need not be duplicated in reports required in III(H). Nothing in this condition shall relieve C-b of its obligation to insure maintenance of the NAAQS.

IV. GENERAL

This permit is issued in reliance upon the accuracy and completeness of the information set forth in C-b's application (See Appendix 2) to EPA for permission to commence construction and operate. Each and every condition of this permit is a material part hereof and is not severable.

By commencing construction and operations pursuant to this conditional permit, C-b will be altering the status quo. Risk of loss to C-b from the inability to meet the provisions of this conditional permit lies solely with C-b as a result of its acceptance of the benefits conferred herein.

for David A. Wagoner
Alan Merson, Regional Administrator

Appendix 1

C-b PSD Dtermination Documents

1. 40 CFR 52.21; Significant Deterioration of Air Quality; December 5, 1974.

2. 42 USC 7401 et. seq.; Clean Air Act Amendments of 1977; August 7, 1977.

3. September 19, 1977, letter from Mr. Jeffrey M. Gaba to Mr. Alan Merson

4. October 4, 1977 letter from Mr. Alan Merson to Mr. Robert A. Loucks

5. October 3, 1977, letter from Thomas H. Truitt to Mr. Alan Merson

6. October 19, 1977 letter from Mr. Thomas H. Truitt to Mr. Alan Merson

7. October 25, 1977, letter from Mr. Thomas H. Truitt to Mr. Alan Merson.

8. November 1, 1977 letter from Mr. Alan Merson to Mr. Thomas H. Truit.

Appendix 2

C-b PSD Review Materials

1. October 14, 1977, PSD Application submittal cover letter from Robert A. Loucks to David A. Wagoner containing ---

    a. PSD application narrative
    b. Fugitive Dust Emission Permit Application
    c. Air Quality Control Plan for Tract C-b
    d. The Stretford Process
    e. The application of the Stretford Process to the purification of natural gas
    f. Overall Project Guide Schedule
    g. Environmental Monitoring Program for Oil Shale Tract C-b
    h. Final Environmental Baseline Program, Volume 3, Meteorology Air Quality and Noise

2. October 24, 1977, letter from Robert A. Loucks to David A. Wagoner providing clarification on emissions.

3. October 31, 1977, letter from Robert A. Loucks to David A. Wagoner providing clarification on emissions.

4. Socio Economic Assessment - Tract C-b, Volume I, Baseline Description and Volume II, Impact Analyses.

5. Modifications to Detailed Development Plan, February 1977.

6. Supplemental material to Detailed Development Plan Modifications, July 21, 1977.

7. December 6 public hearing testimony and associated written materials which are part of the record.

Appendix 3

EPA Analyses/C-b

1. Memo - Thoem to C-b PSD file regarding C-b PSD Air Emissions

2. Memo - Theom to C-b PSD file regarding Additional C-b Detail

3. Memo - Thoem to C-b PSD file regarding BACT Determination

4. Memo - Theom to C-b PSD file regarding Evaluation of Proposed Monitoring

5. Memo - Thoem to C-b PSD file regarding Associated Growth Analyses

6. Memo - Thoem to C-b PSD file regarding Attainment of NAAQS

7. Memo - Thoem to C-b PSD File regarding visibility

8. Memo - Henderson to C-b PSD file regarding air quality modelling

9. Public Notice of Proposed Conditional Permit to commence construction and operate - C-b

10. Public Notice -- C-b -- Notice of Hearing and Summary of Conditions

11. Letter from Mr. David A. Wagoner to Mr. Craig Rupp regarding Federal Land Managers air quality responsibilities

12. Letter from Dr. Cooper Wayman to OSEAP members regarding Federal/State/Local comment on proposed Conditional Permit

13. Letter from Mr. David A. Wagoner to Mr. Robert A. Loucks regarding Proposed Conditional Permit

14. Letter from Mr. David A. Wagoner to County and Local Officials regarding Proposed Conditional Permit.

15. Memo - Thoem to C-b PSD file regarding C-b PSD emissions - addenda.

16. Memo - Thoem to C-b PSD file regarding Associated Growth Analyses - Addenda.

17. Memo - Thoem to C-b PSD file regarding Maintenance of NAAQS - addenda.

18. Memo - Thoem to C-a and C-b PSD files regarding Visibility Degradation on the Flat Tops Wilderness Area - Addenda.

19. Memo - Thoem and Henderson to C-a PSD files regarding Modelling for C-a and C-b --- Adenda.

20. Memo - Thoem to C-b PSD file regarding Public Hearing Testimony and written submissions.

APPENDIX 13.0

Regional Transportation and Population Studies - All Energy Projects

APPENDIX 13.0

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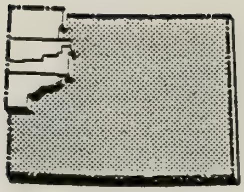
A

APPENDIX 13A



COLORADO WEST TRANSPORTATION PLAN

Prepared for the Colorado West Area Council of Governments

March, 1980

By:

TDA INC.

Seattle/Boulder

In association with
Bowers/Chambliss

With special assistance from:

CH2M-Hill
Isbill Associates
Seattle Engineering International
Kaiser Engineers
Dr. Peter Loubal
Mr. Robert Kessler

Colorado West Area Council of Governments

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Executive Summary

The Colorado West Transportation Plan deals with the impacts of increased energy development on the regional transportation systems of Garfield, Mesa, Moffat and Rio Blanco Counties in Northwest Colorado. Included in its transportation concerns are the regional highway network, the airports, and because of their importance to the hauling of products, the rail and pipeline systems. While the emphasis is on regional impacts of energy development, the continuing needs of recreational, industrial and agricultural activities are built into the process.

The regional problem is one of great complexity. There are wide ranges of expectations for energy development and, at least theoretically, there is a wide range of transportation alternatives — truck, coal slurry pipelines, oil pipelines, air, rail and almost an endless variety of combinations in between.

The Colorado West Transportation Plan final report is intentionally brief. Our objective is to provide a simple, straightforward guide to policy and potential actions in the four counties, and not to add to the complexity of the situation.

For readers wanting more detailed backup information, there are two supporting documents:

Technical Notebook. This provides details of data and analyses used in preparing this summary report.

Piceance Creek Roadway Report. This technical document describes the analysis of alternative routes in the Piceance Creek Basin.

The impact of energy development on the regional roadway system will be significant. In particular the potential for a high number of heavily loaded energy trucks to deteriorate pavement structure, increase congestion and impact the existing communities will arrive concurrent with energy development. The need to transport employees from their homes in existing settlements to remote energy development sites will place increasing volume demand on the capacity of the existing roadways.

The Colorado West Transportation Plan documents the impacts and identifies the future transportation needs of the region. As an overview of the report's contents and findings, a chapter-by-chapter summary follows.

Chapter 1. Introduction

This chapter provides a background perspective on why this particular study was done. U.S. energy consumption continues to increase while our production is declining. The problems of higher levels of energy import lead to political and economic pressure to

develop alternative available sources in the U.S. With their large resources of coal, oil shale, oil, gas, uranium and other minerals, Garfield, Mesa, Moffat and Rio Blanco Counties become a center of vital national interest.

Chapter 2. Today's Travel

This chapter describes the existing system of roadways, airports, rail and pipelines. Travel growth rates in this region are higher than average, and reflect energy development already underway.

Chapter 3. The Region's Population and Employment

The purpose of this chapter is to describe alternative "scenarios" of growth. These scenarios become the basis in later chapters for estimating future travel needs. Three different scenarios of population and employment growth for each of the four counties were developed and related to levels of energy resource development. These are summarized below for 1985 and 2000.

Regional Growth Scenarios — Garfield, Mesa, Moffat, and Rio Blanco Counties

				Energy Production Level	
		Regional Population	"Energy" Employment	Coal Tons/Yr.	Oil Shale Barrels/Day
Today	1979	115,000	3,900	7 million	0
Future:					
Scenario I	1985	145,000	*	*	0
	2000	225,000	*	*	0
Scenario II	1985	190,000	10,500	17 million	42,000
	2000	275,000	10,200	19 million	205,000
Scenario III	1985	225,000	23,200	26 million	100,000
	2000	360,000	26,500	34 million	640,000

*No separate projections were made

Chapter 4. Tomorrow's Travel Needs

The purpose of this chapter is to describe the impact of projected growth on the region's probable transportation system. Because it represents a more likely set of events than either of the extremes, the "mid-range" Scenario II is used as the basis for these comparisons. This, and the next chapter, test the validity of certain assumptions about the transportation network. The most important of these assumptions were:

1. Personal transportation in the region will still depend primarily on the private automobile, but for certain kinds of trips, increasing emphasis is placed on carpool and vanpools.
2. Because of the long-term economic advantages of pipelines, crude oil products from oil shale will move by pipeline. Trucks may be used during initial operations and for some of the by-products.
3. In general, coal will move out of the region by rail. Long distance haul by truck is too expensive and market conditions won't support coal slurry pipelines.
4. Because of the volume of products, rail service extensions to Lay (underway) and to the Superior site were assumed.

A computer-based process — TDA/TANDEM — was used to project future travel loads on the future transportation network. Dramatic increases in highway traffic, particularly heavy truck traffic, create need for a continuing program of widening and repaving of the State Highway network, increased need for urban bypasses and need for significant improvements in rail and pipeline capacity.

Chapter 5. Transportation Alternatives

This chapter discusses variations to the projected future highway, transit, rail, pipeline and air systems. Included is an analysis of alternative roadway patterns serving the Piceance Creek Basin. In general, this chapter explains why variations such as coal slurry pipelines and air freight were found not to be workable.

Chapter 6. Recommendations

This chapter describes specific recommendations for each of the major systems.

1. For highways, there should be a regional highway improvement program totalling about $220 million (in 1979 $) through the year 2000. However, of more importance is the identified need for approximately $75 million (in 1979 $) between now and 1985. Specific projects and their timing are identified in Table J of Chapter 6. In addition, the counties should adopt a roadway plan for roads in the Piceance Creek Basin, even though current projections do not justify construction of these roads now.
2. Because transit is an important element in minimizing the impact of energy development, a regional transit development plan should be prepared covering all developing areas and intercity connections.
3. Air System. About $45 million worth of airport improvements are recommended to bring the region's airports into a recommended system plan:
   - Grand Junction (Walker Field): larger air carrier airport
   - Hayden: small air carrier airport
   - Rifle/Garfield County: commuter service/small air carrier
   - Craig: commuter service
   - Meeker: commuter service
   - Rangely: commuter service
4. The rail system should extend to Superior by 1990. This is vital because of the favorable impact the rail line will have on reducing highway volumes on key highway links and through towns.
5. Pipelines. As closely as possible, construction of pipelines should be completed on the same schedule as opening of oil shale plants for other than pilot plant productions.

These overall system recommendations are followed by specific recommended actions for each of the major responsible agencies including:

- The Colorado West Area Council of Governments
- The Counties
- The Cities and Towns
- Colorado Department of Highways
- Energy Projects
- Federal Agencies

The last section of "Recommendations" defines a general approach to a financing strategy. The recommended approach to assignment of financial responsibility is:

1. The direct energy needs should be supported by the energy projects themselves. Whether that payment comes from the private energy developer or the Federal Government depends in large measure at the national level on the degree to which our national synthetic fuels program will move ahead in the private sector versus how much it will be a Federal energy program.
2. In the long run, the existing local and state tax structures may be able to pay for the indirect energy costs of providing transportation services to a growing population. However, the schedule of development may well be more nearly related to national needs than the local area's ability to absorb that growth. The costs of serving rapid growth are higher than those of a more orderly pace and the costs occur much more quickly than do the local and state revenues that will be derived from that growth. Therefore, the energy projects, whether by private or Federal money, should reasonably help support both the extra costs of rapid growth and the cash flow problems of income lagging behind expense. The highway needs present a clear example of the financing problem. It is estimated that existing sources will not be able to meet even one-fourth of the expected needs.

1 Introduction

Purpose

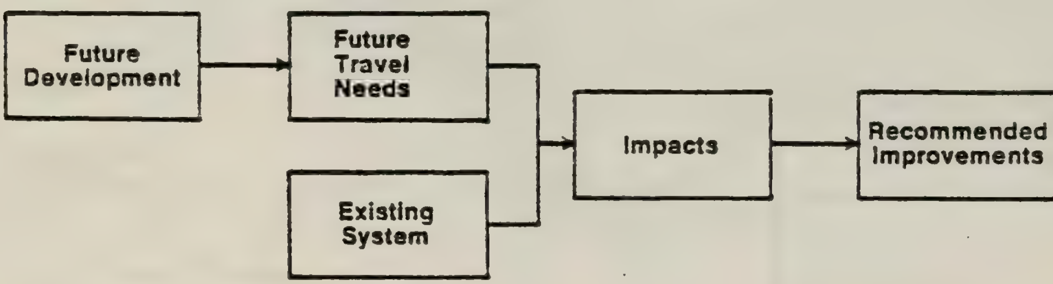
The four northwest counties of Colorado — Mesa, Garfield, Rio Blanco and Moffat — have historically based their economy on agriculture and tourism. However, this study is not stimulated by the needs of those activities, but by present U.S. energy problems and the natural energy resources of these counties. These four counties have a major share of the U.S. oil shale resources. In addition, there are vast resources of high quality coal and, to a lesser extent, resources of oil, natural gas, and uranium.

As U.S. energy needs increase and as traditional resources decline, pressure for development of Northwest Colorado resources will increase. The purpose of this study is to address the transportation needs resulting from increased energy extraction from these four counties.

The most important study activities have consisted of making projections of future energy development, developing a system for relating these projections to travel needs for both persons and goods, identifying the impact of these needs on the existing transportation system and recommending system improvements. See Figure 1.

The focus has been on those portions of the four counties with active or potential energy development. This study area is shown in Figure 2.

Figure 1 Major Study Activities



National Perspectives on Energy

Major development in this region depends on national decisions concerning energy. Therefore, it seems appropriate to set a brief perspective on national energy requirements.

U.S. total energy requirements have increased rapidly. Figure 3 shows the increase in total energy consumption from 1925 through 1978. This energy requirement has been a result not only of increasing population but also of increasing consumption per person. Figure 4 illustrates the per capita increase in energy requirements from 1925 through 1978. During this period the per

capita consumption has doubled to the equivalent of about six gallons of oil per day. Figure 5 summarizes the sources from which the U.S. has met these energy requirements. Crude oil and natural gas have become increasingly important. In contrast, Figure 6 shows our own U.S. energy production by source. Since 1970 U.S. "production" has dropped, in spite of the continued rise in "consumption." The difference represents net imports. Figure 7 shows our increasing dependence on foreign oil. Today, about half of our petroleum needs are satisfied with imports.

Figure 3 U.S. Daily Energy Consumption by Year

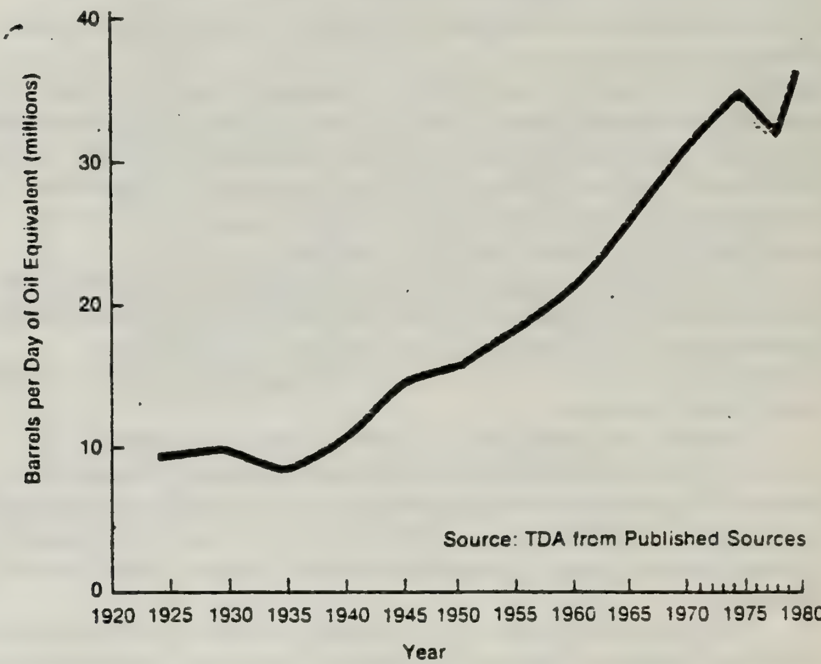
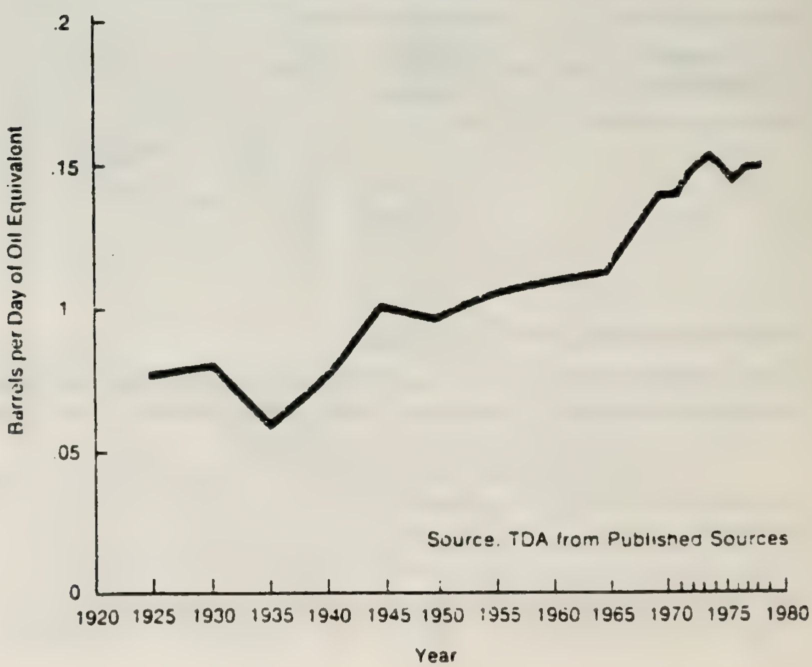


Figure 4 U.S. Daily Energy Consumed per Person (In Equivalent Barrels of Oil)



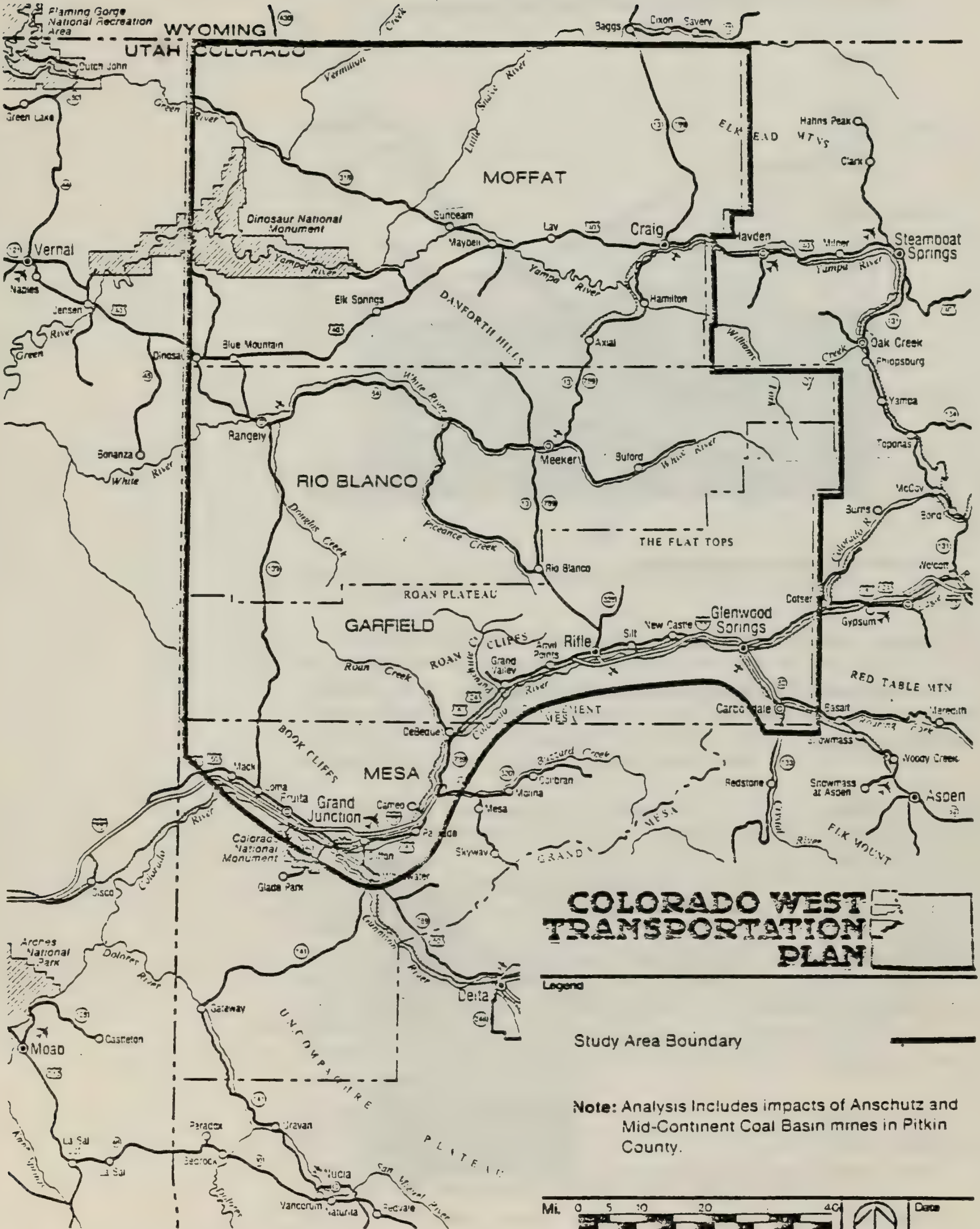
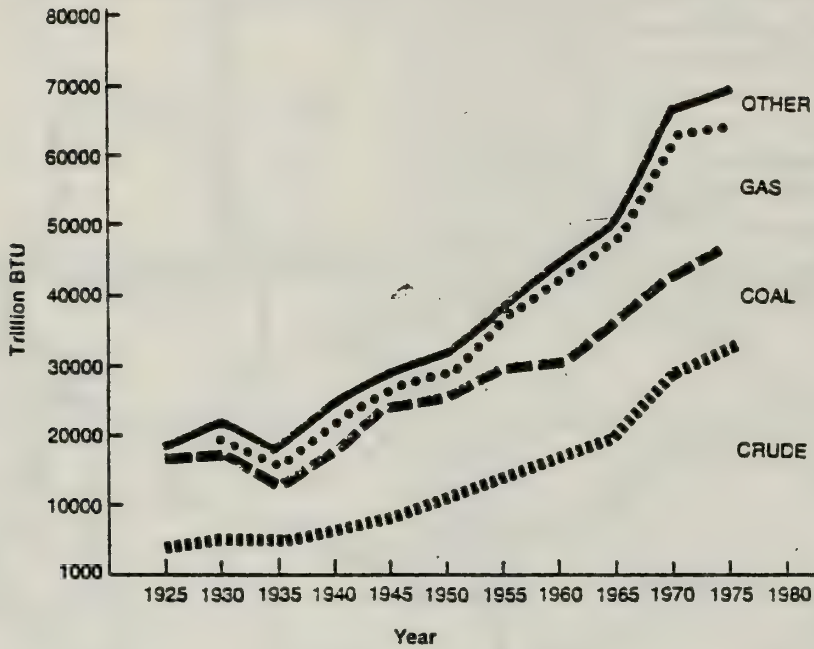


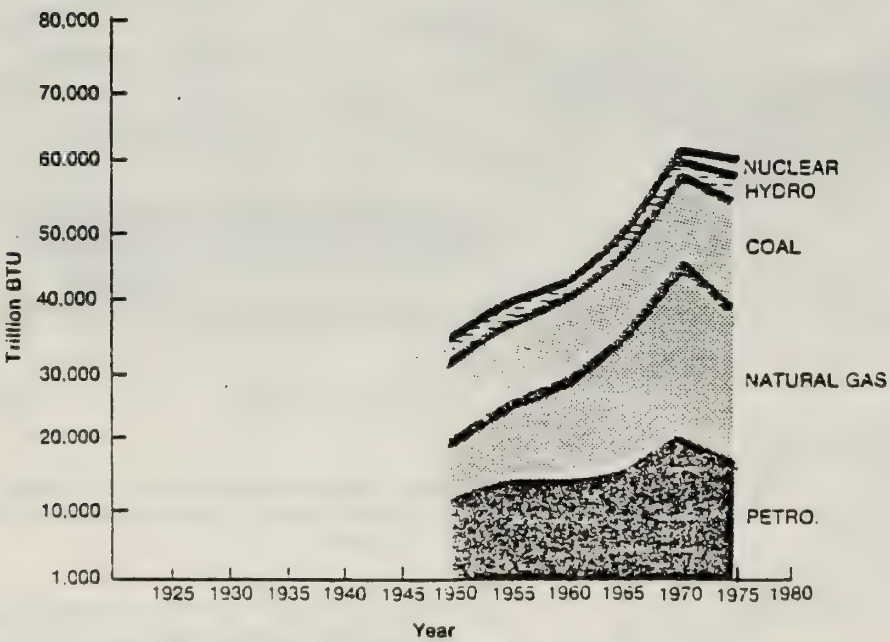
Figure 2 Study Area

Figure 5 U.S. Energy Consumption by Source



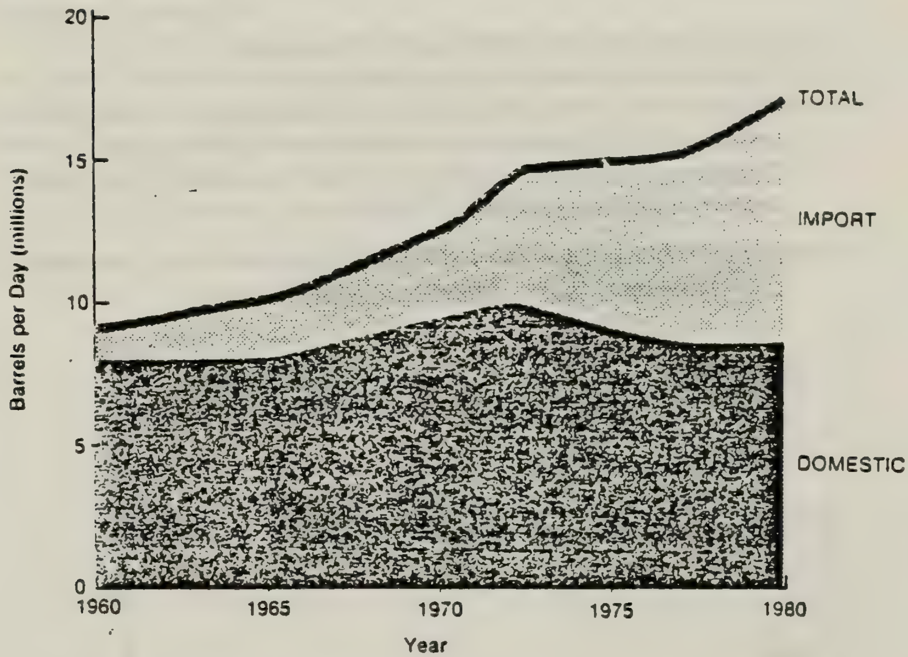
Source: TDA From Published Sources

Figure 6 U.S. Energy Production by Source



Source: TDA From Published Sources

Figure 7 Trend of U.S. Oil Consumption by Source (Domestic & Import)



Source: TDA From Statistical Abstract of U.S., 1978, & Energy Future, Random House, 1979.

The U.S. has experienced two recent energy "crises" related to these imports. The first came in 1973-1974 with the first Arab embargo on oil shipments. This led to President Ford's "Project Independence." In 1979 the Iranian revolution and the resulting drop in Iranian oil exports triggered the current "crisis." President Carter, in July 1979, announced a program that would:

- Limit and, later, reduce oil imports.
- Develop alternative sources of energy, including coal, oil shale and solar.
- Establish a conservation program.
- Encourage utilities to use fuels other than oil.

Of particular significance to the four northwest corner counties of Colorado is the program for development of synthetic fuels. Of eight oil shale facilities recommended in the President's program, up to six could be in Garfield and Rio Blanco Counties. One of the 41 potential sites identified by the U.S. Department of Energy for coal liquefaction is in Moffat County.

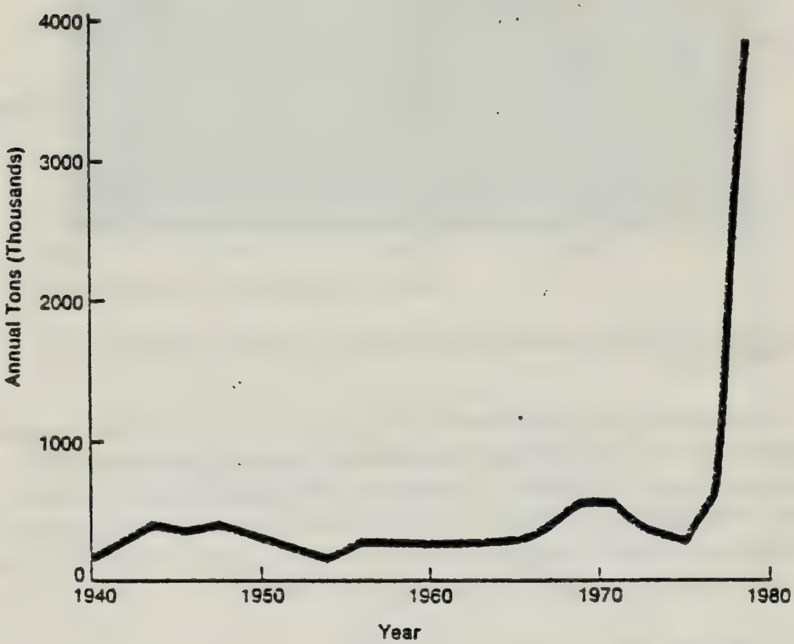
Local Activity

After a dormant period, coal activity in the four northwest counties is booming. Figure 8 illustrates coal extraction from these counties from 1940 to 1978. Production for 1979 is estimated at about 7 million tons. (Note: this includes Anschutz and Mid-Continent coal mine production from Pitkin County which impacts the Study Area). Several major energy/coal companies in the U.S. have lease properties in the four northwest counties. Coal in this area is of high

quality — low sulphur and high BTU. Demand for this coal is heavily dependent on:

- Local demand within the State of Colorado.
- Transportation costs to major markets.
- Environmental requirements and the degree to which they emphasize the need for high quality, low sulphur coal.
- Other alternative energy sources and the status of particular development with respect to the permit and leasing process.

Figure 8 History of Coal Production in Colorado West Counties (Garfield, Mesa, Moffât and Rio Blanco)



Source: TDA

Colorado coal must compete with the low-cost, but lower-quality coals of the Powder River Basin in Wyoming. Because transportation costs weigh heavily in coal's total cost at the marketplace, Colorado coal must compete with other resources closer to major markets: coal reserves of Utah to the west, lignite in the southwest and coal to the east in Illinois and through the Appalachia area.

Oil shale has been in a budding stage for decades; it perpetually is about to blossom. The first pioneering efforts to extract petroleum from oil shale began in this area at least 60 years ago. During World War II, the Bureau of Mines embarked on the Anvil Points Project near Rifle, Colorado. Additionally, the Union Oil Company operated a pilot plant in the Parachute Creek Drainage during the 1950's. The economics of oil shale have remained elusive over the years. To date, limited plant development type operations have been pursued.

Public Participation

This study has been guided by a Transportation Steering Committee (TSC). This committee, representative of several interests in the region, has worked with the planning team throughout the course of

the study. Meeting with the consulting team approximately six times during the course of the analysis, the TSC has acted as a sounding board for the planning team, advising on the suitability of the direction of the effort.

In addition, public forums have been held in each of the four counties. The first round of forums, held during March of 1979, sought public input on major issues. The second round, held during September of 1979, reviewed the major study findings and recommendations.

2 Today's Travel

This chapter summarizes the region's existing transportation system, its current use, planned changes, and present funding.

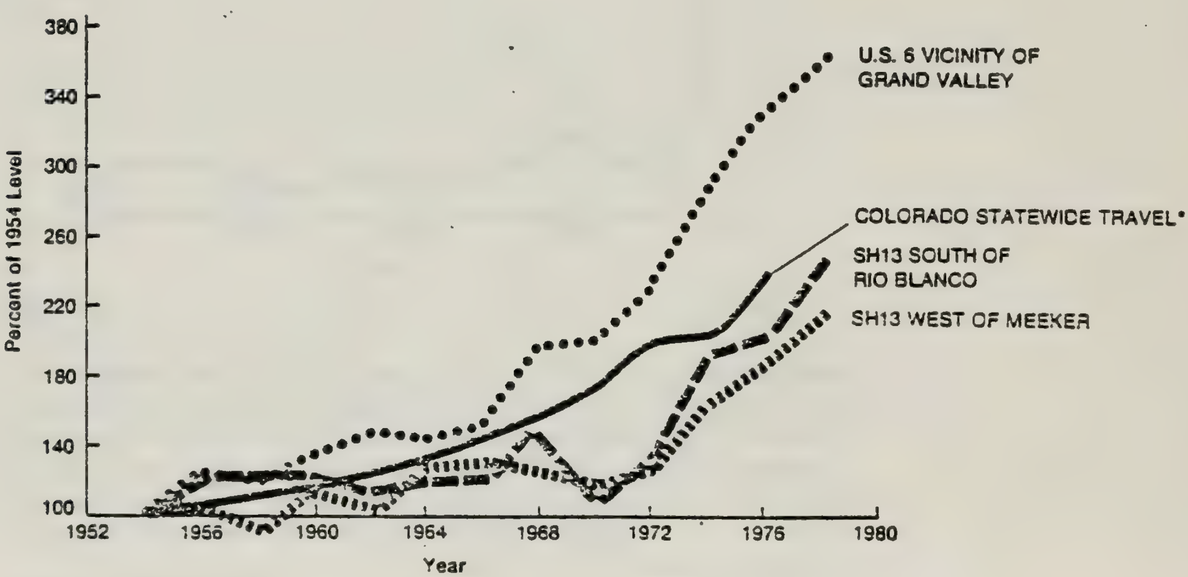
Highway Network

Regional

The regional roadway network is summarized in Figure 9. The region is served by two U.S. numbered routes in the east/west direction — I-70 on the south and U.S. 40 to the north. Colorado State Highway routes 13, 82, and 139 are the main north/south routes.

Figure 10 summarizes existing traffic volumes on the regional roadway network. Figure 11 shows the travel growth rates for a few key locations in the region and compares them with statewide averages. Note that since 1970, traffic growth in the region has been higher than the statewide average.

Figure 11 Relative Highway Traffic Growth at Selected Locations 1954-1978



*Outside Incorporated Areas

Source: TDA from CDH Data

Current Highway Department expenditures for improvements to non-interstate state highways in this area are in the $2 - $3 million annual range. These expenditures do not reflect maintenance, administration, and miscellaneous expenditures, which are typically in the $½ - $1 million annual range.

The Five Year Highway System Construction/Improvement Program (1980-1984) details programmed State Highway

improvements throughout the state. These are projects for which the major decisions have been made and which have become part of th- program of implementation. Within the study area, these projects over the next five years include completion of I-70 from Anvil Points, west of Rifle, to DeBeque Canyon and widening of segments of State Highways 13, 82, and 146. Also, construction will be under way on I-70 in Glenwood Canyon. The locations of these programs are shown in Figure 12. Costs are shown in Table J in Chapter 6.

Local

Supplementing the regional roadway network is the local roadway system of country roads and city/town streets. In 1978, approximately $11 million were expended on roads and streets by the counties and the cities in the four counties. This total includes construction, maintenance, administration and other expenditures. Table A breaks the total down by County, City, and source of funds. Because this report is regional in scope, overall needs at the local level are not specifically identified herein. However, it is assumed that the local roadway system will continue to be expanded and maintained subject to fiscal limitations and local decision-making processes.

Table A Present County and City Roadway Funding (Calendar Year 1978)

	Source				
	Local Funds	Colorado Highway User Tax Fund	Federal Assistance	Other	TOT.
County Roads					
Garfield County	231,571	600.650	251,869	113,993	1.198.083
Mesa County	578.984	1,403,204	496.327	256.816	2.735.331
Moffat County	485.564	1,057.951	182.512	300.792	2.026.829
Rio Blanco County	221,888	707,876	191.318	29.951	1.151 033
Town & City Streets					
Carbondale	47,823	9.568	25,700	47.511	130.602
Collbran	4,301	2,130	----	3,121	9.552
Craig	396.099	47.377	----	72,360	515,336
DeBeque	3,042	2,049	3.394	2.690	11,175
Dinosaur		2.276	----	1,432	3.708
Fruita	116.807	13.651	21.864	8.360	160.702
Glenwood Springs	217.936	26.157	----	10.034	254.127
Grand Junction	1,848.970	152.807	97.505	490.705	2.569.987
Grand Valley	1	2.561	----	1,316	3.878
Meeker	24.508	12.543	7,500	12.313	56.864
New Castle	5.615	2.359	----	3.149	11.123
Palisade	31 611	5,738	----	11.350	48 699
Rangely	59.054		----	11.647	70.701
Rifle	149.651	13,181	32.683	8.460	203 995
Silt	2.784	4 985	----	4 771	12.540
TOTAL	4.426 209	4.067 073	1.310.672	1.390.811	11 194.765

Source: Colorado Department of Highways

Rail Network

The rail network in the region is shown in Figure 9. The main east-west line of the D&RGW parallels I-70 along the Colorado River. Another major D&RGW line serves the region through Craig. These lines connect to the Eastern Slope through the Moffat Tunnel and over Tennessee Pass.

Figure 9

Existing Regional Roadway Network, Rail, and Air Systems in the Study Area

Figure 10 Traffic Volumes — 1978 Annual Average Daily Traffic

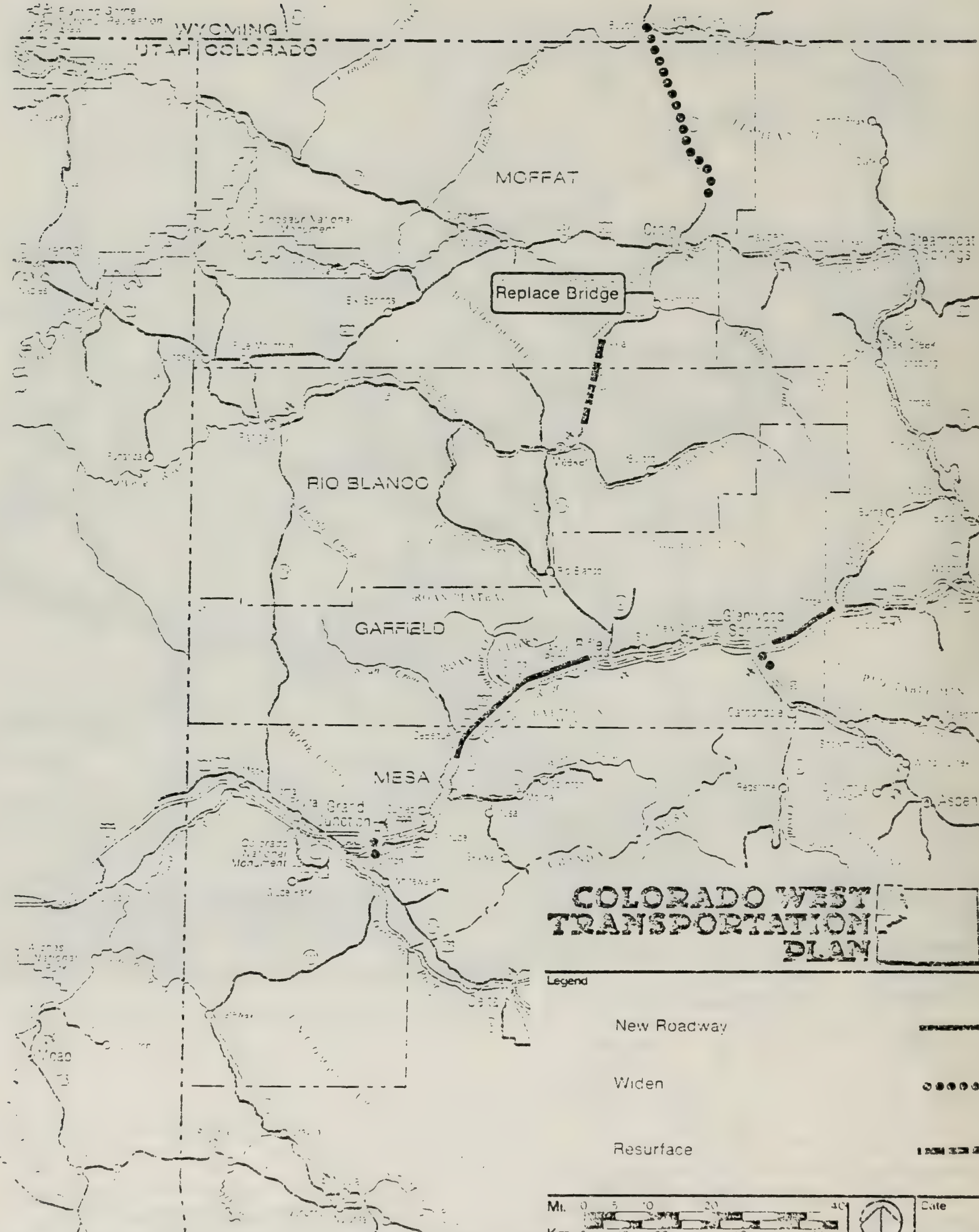


Figure 12 Study Area Roadway Improvements Programmed by the State of Colorado. 1980-1984.

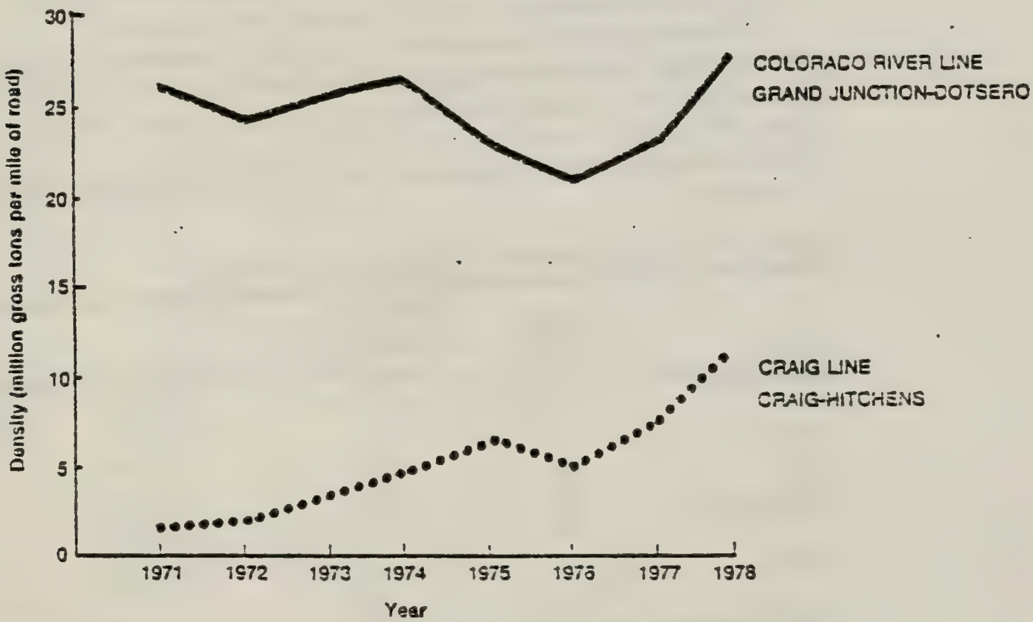
Recent trends of freight traffic on the D&RGW lines are shown in Figure 13. Note that while this traffic has remained generally constant on the Colorado River line, it has increased dramatically on the Craig line.

The D&RGW has recently renovated the Craig line with heavy rail, centralized traffic control and added sidings. Extension of the D&RGW spur line from Craig to the COLOWYO mine was completed in 1979. Currently, the D&RGW is proceeding to build a spur west from Craig towards Lay.

There has been discussion of a Union Pacific line coming down from Wyoming into the area west of Craig. The UP has done some investigation of this possibility; however, information developed during this analysis indicates that currently there are no plans to proceed.

In general, rail facilities are privately financed, except for some right-of-way easements and leases on public land.

Figure 13 Growth of Rail Traffic



Source: D&RGW

Air System

Aviation services for the study area are provided by seven key airports. As shown in Figure 9, these are located at Grand Junction (Walker Field), Hayden (Yampa Valley, Routt County), Craig (Craig-Moffat County), Rifle (Garfield County), Meeker (Meeker), Rangely (Rangely), and Aspen (Sardy Field, Pitkin County).

Grand Junction's Walker Field is the principal aviation facility serving the study area and is one of three airports providing certificated air carrier service. Its key facilities include an airport traffic control tower (ATCT), a precision instrument landing system (ILS), and an on-site flight service station (FSS). Its primary runway can handle jet aircraft in the B-737 and B-727 family. Larger DC-8 aircraft have utilized Walker Field under ski charter operation.

Yampa Valley Airport in Hayden, Routt County, is also an air carrier airport. Although not physically located within the study area, Hayden's service area extends into Moffat County. Frontier Airlines serves Hayden with Convair 580 aircraft.

Similarly, Sardy Field in Aspen, Pitkin County, also an air carrier airport and also not physically located within the study area, has a service area which extends into Garfield County. It has key facilities such as an airport traffic control tower (ATCT) and a privately owned microwave landing system (MLS). Scheduled service to Sardy Airport is provided on Convair 580 and DASH 7 aircraft.

The remaining four airports at Craig, Rifle, Meeker and Rangely are non-air- carrier facilities. Craig has air commuter service at this time, while the others are general aviation facilities only.

Table B summarizes key service and operational characteristics of these airports.

Figure 14 shows the growth trend of air passenger travel at Grand Junction's Airport.

Figure 15 shows the trend of general aviation operations (take-offs and landings) at select airports in the region.

Airport expenditures are highly variable, depending heavily on commitments of Federal funds by the FAA to specific projects. Most of the region's airports have completed master plans for upgrading. The schedule for these improvements depends upon Federal Aviation Administration funding approval. Specific needs are described in Chapter 4.

Table B Characteristics of Study Area Airports

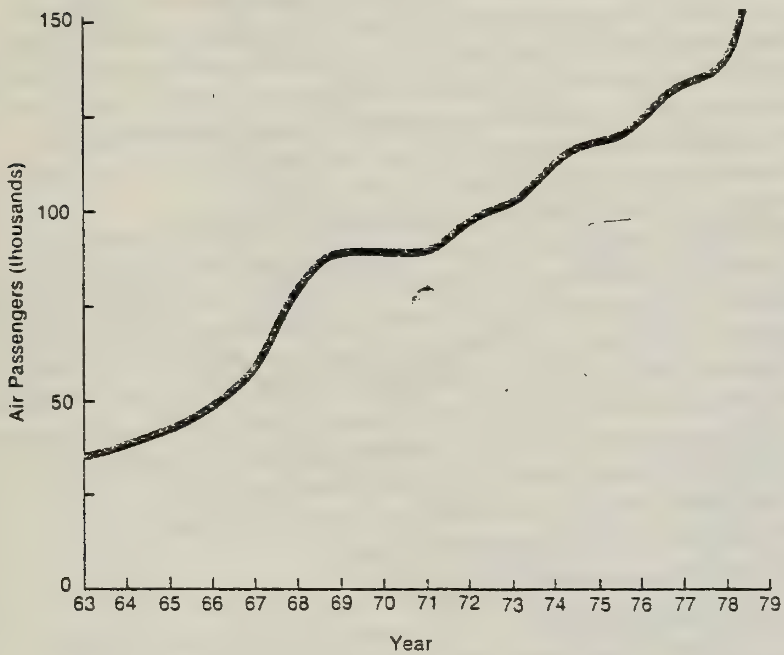
Location	Service Level, 1979	Estimated[1] Total Aircraft Operations (thousands) 1978	Runway Length, Feet	Comments
Grand Junction	AC	81	1 @ 10.500 1 @ 5.365	ATCT ILS FSS
Hayden	AC	22	7.000	
Craig	CS	13	5.600	
Rifle	GA	15	5.155	
Meeker	GA	27	4.500	
Rangely	GA	45[2]	1 @ 4.500 1 @ 2.400	
Aspen	AC	45	6.000	ATCT MLS

Legend:
AC = Air Carrier (certificated)
CS = Commuter Service
GA = General Aviation
ATCT = Airport Traffic Control Tower
ILS = Instrument Landing System
MLS = Microwave Landing System
FSS = Flight Service Station

1 Principal Source: FAA Airport Master Record Form 5010-1 1978

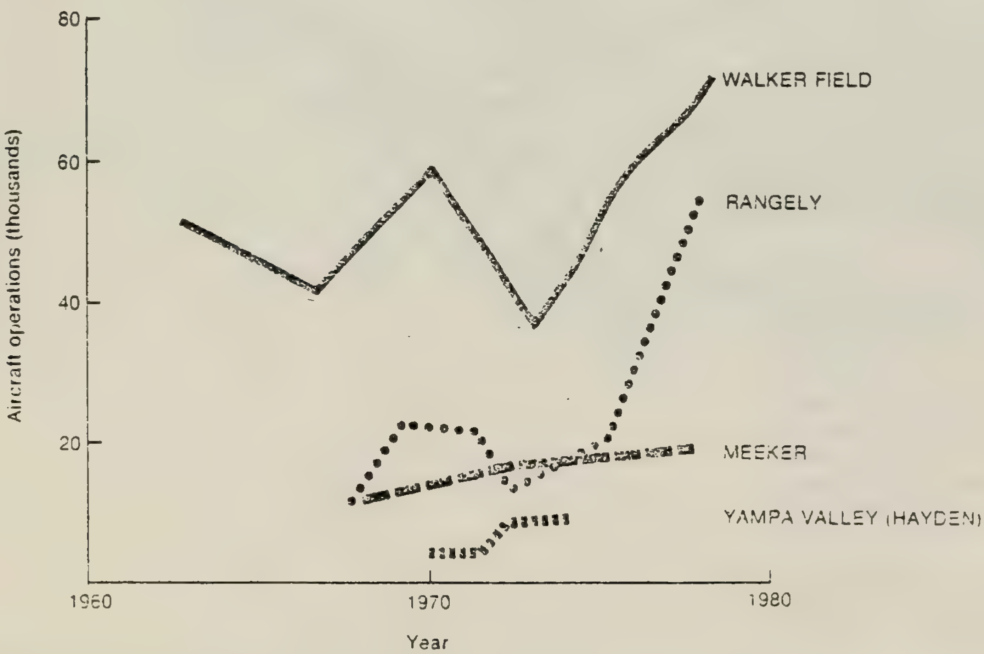
2 Approximately 30% of Rangely's operations are generated by the community college's student pilot program.

Figure 14 Trend of Annual Passenger Boardings at Walker Field (Certificated Air Carriers Only)



Source: TDA & Walker Field

Figure 15 Annual General Aviation Operations at Selected Airports



Source. TDA

Transit Service

Figure 16 shows the location of existing transit service systems. Intercity public transportation service is provided in all of the major highway corridors, except for the Colorado State Highway 64 and 1__ routings. Rangely is thus isolated from the rest of the region from an intercity bus transportation standpoint. Specialized elderly and handicapped transportation services are provided by a number of social service agencies throughout the region.

Transit services are being supported by several private organizations. Employers providing transit services include Mid-Continent Coke and Coal, Rio Blanco Oil Shale Project (Ca) and Occidental Oil Shale Inc. (Cb). Funding of specialized elderly and handicapped services is provided through a combination of local contributions and grants from Federal programs. Roughly $100,000 are expended annually in providing these elderly and handicapped services throughout the region. Intercity service is provided by both locally and nationally owned private bus companies.

There are no known *committed* programs for transit improvements in the region at this time.

Pipeline and Transmission Corridors

Existing pipelines and electric transmission corridors are shown in Figure 17. Environmental impact statements for oil shale development have discussed pipelines for shipping the crude product. However, there are no announced plans to move ahead at this time. It is noted that there currently exists additional capacity in some existing pipelines. Also, pipeline and electric transmission facilities, like railroads, are privately financed, except for some right-of-way easements and leases on public lands.

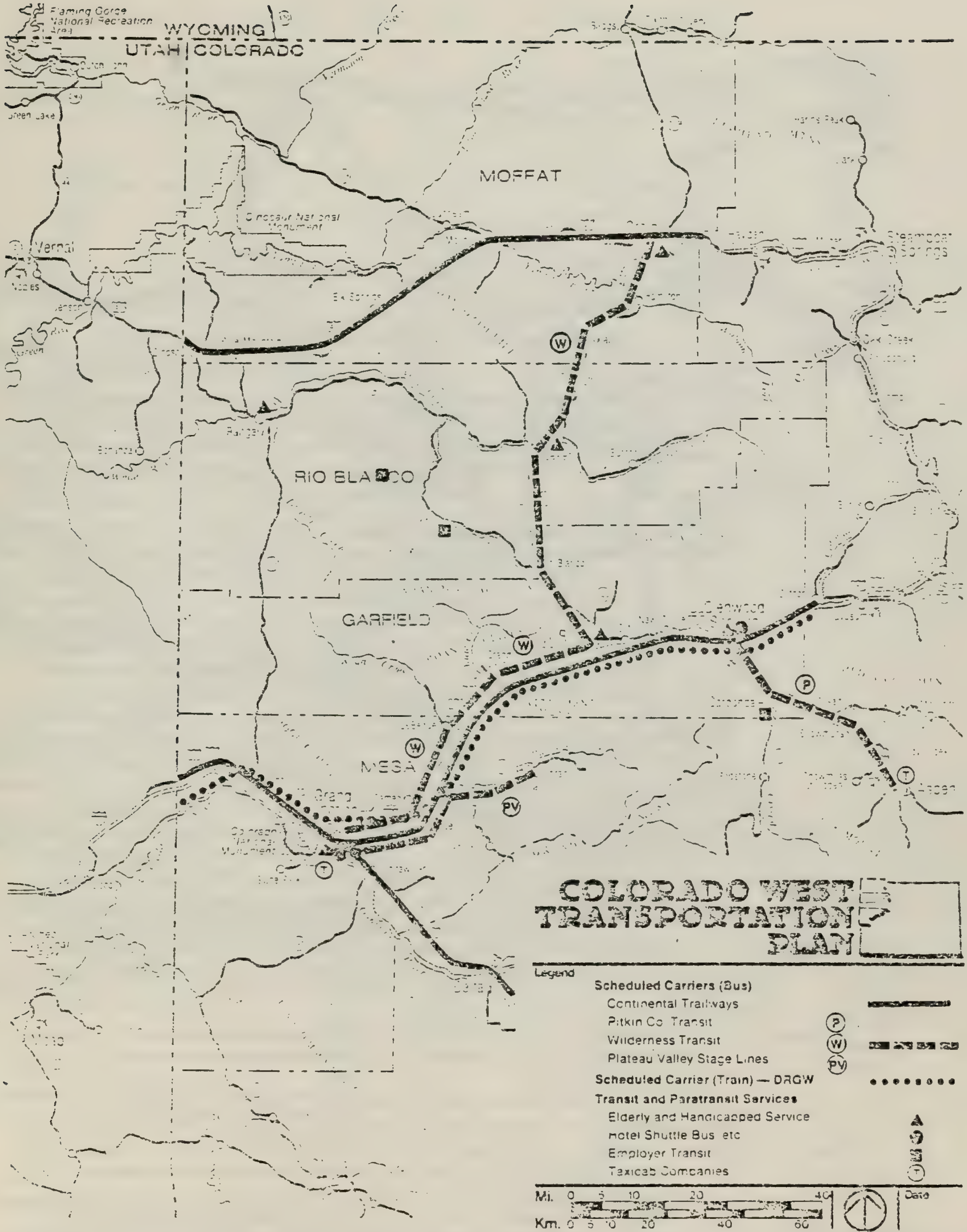


Figure 16 Existing Transit Service Systems

TDA Transportation Development Associates Inc.

Figure 17 Oil & Gas Facilities & Electric Transmission Corridors

3 The Region's Population and Employment

The purpose of this chapter is to describe alternative scenarios of population and employment growth as a basis for projecting future travel needs. It introduces these scenarios by describing the four counties, their present populations and current energy activity.

The Setting

Moffat, Rio Blanco, Garfield and Mesa Counties, comprising the Colorado West Area Council of Governments region, cover 14,300 square miles in the northwestern corner of Colorado. Until very recently, the basic economy of the area consisted primarily of agriculture and tourism/recreation. However, the region is now facing potential massive changes as a result of the development of the vast energy resources underlying much of the four-county area. Here resources include coal, oil shale, uranium, oil and gas; their general locations are shown on Figure 18. Physically, the four-county area includes the lower half of the Yampa River drainage, nearly all of the White River drainage, the lower portions of the Colorado River within Colorado, plus small portions of the Dolores River drainages. These rivers and their steep walled canyons, along with the rolling hills and plateaus, are a major determinant of the form of the transportation system within the region.

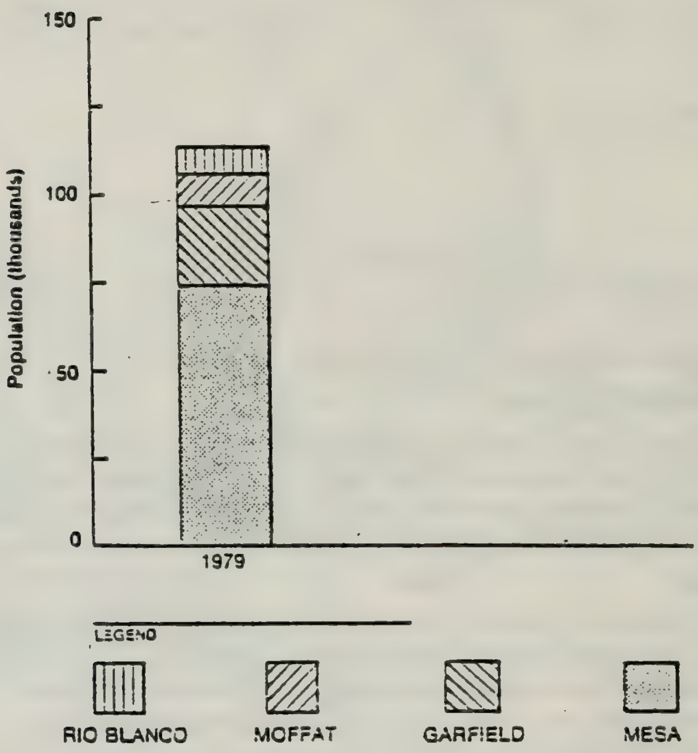
Approximately 65 percent of the land in the region is publicly owned, with the Bureau of Land Management and Forest Service being the principal landholders. Private lands tend to be concentrated in the river and stream valleys, but also include most of eastern Moffat County and large areas immediately east of Meeker.

Existing Population

Since 1970, population in the region has grown by about 40 percent to a present population of about 115,000. Its distribution by County is shown in Figure 19.

About half of the regional population resides within the boundaries of the cities and towns. The largest incorporated area in the region is Grand Junction (estimated 1979 population - 28,000), the commercial hub of western Colorado located at the confluence of the Colorado and Gunnison Rivers; Craig (7,000) in Moffat County on the Yampa River is second in size; followed by Glenwood Springs (4,300) at the junction of the Colorado and Roaring Fork Rivers. Most of the other half of the population is located in the fringe areas next to the cities and towns.

Figure 19 Present Regional Population by County



Source: CWACCG

Present Energy Activity

Much of the population growth that has occurred in the region since 1970 is a result of workers brought into the area to develop the region's energy resources. Major energy development sites are shown on Figure 20.

Growth Scenarios

Three different "scenarios" of population and employment growth were developed to serve as the basis for forecasts of future travel.

Scenarios I and II were based on population projections made by the Colorado West Area Council of Governments[1]. Scenario I is based upon natural population growth without energy development. Scenario II adds growth resulting from an extensive development of the region's coal and oil shale resources. This Scenario II projection assumed that coal production in the four counties would grow from about 7 million tons in 1979 to 17 million tons in 1985 and to about 19 million tons in 1990. (Note that these estimates include coal production from the Anschutz and Mid-Continent mines in Pitkin County). Oil production from shale was assumed to grow from about 42,000 barrels of oil per day in 1985 to 140,000 in 1990 and 205,000 in 2000.

Scenario III was formulated later in the study in response to questions from the Counties and the Technical Steering Committe on the potential impact of a maximum feasible rate of development

1 "Region XI Population Projections — Municipal and County Population Projections: 1979-2000". Colorado West Area Council of Governments, December 1978.

Figure 18 General Location of Coal, Oil Shale, and Uranium

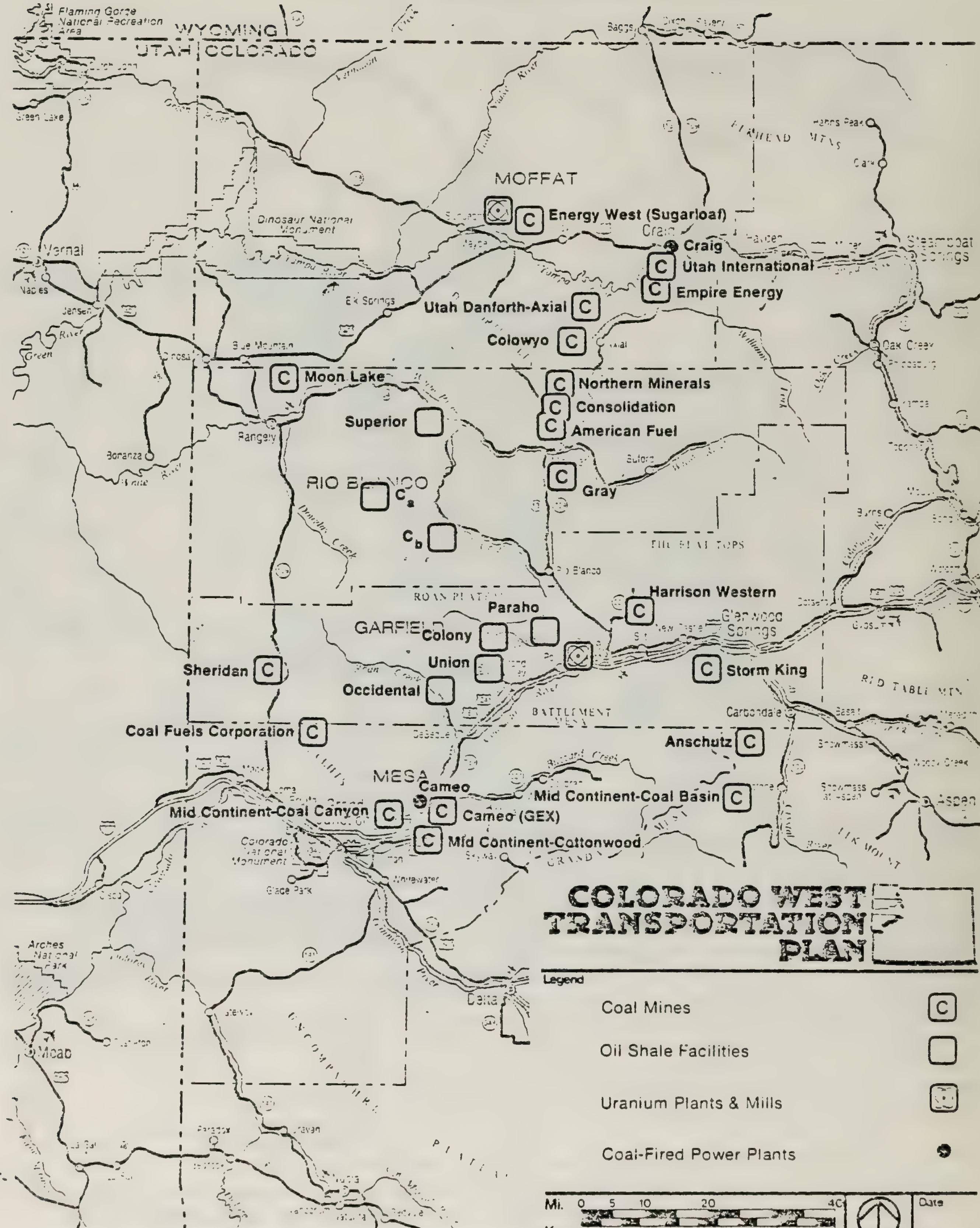


Figure 20 Major Energy Development

of the region's energy resources. This projection assumed that all of the coal mines identified in the regional BLM environmental studies would be developed and that the oil shale industry in the region would grow from a production of approximately 100,000 barrels of oil per day in 1985 to 440,000 in 1990 and 640,000 in 2000.

Scenario II is used as the population and employment "base case" throughout this report — variations for Scenarios I and III are considered separately. A summary of these regional growth scenarios is included as Table C.

Table C Regional Growth Scenarios — Garfield, Mesa, Moffat, and Rio Blanco Counties

				Energy Production Level	
		Regional Population	"Energy" Employment	Coal Tons/Yr.	Oil Shale Barrels/Day
Today	1979	115,000	3,900	7 million	0
Future:					
Scenario I	1985	145,000	*	*	0
	2000	225,000	*	*	0
Scenario II	1985	190,000	10,500	17 million	42,000
	2000	275,000	10,200	19 million	205,000
Scenario III	1985	225,000	23,200	26 million	100,000
	2000	360,000	26,500	34 million	640,000

*No separate projections were made

Basic worker estimates for Scenarios II and III energy development activites are summarized in Figure 21. Even though *production* is expected to grow steadily through 2000, *employment* begins to peak earlier because of the construction of the 1980's and the resultant large number of construction workers. This information was developed through a combination of Council of Government analyses, review of environmental statements, and consultation with energy companies.

Table D indicates the projected populations for the alternative Scenarios considered. The variation in population between Scenarios is most noticeable in those centers with greatest energy development.

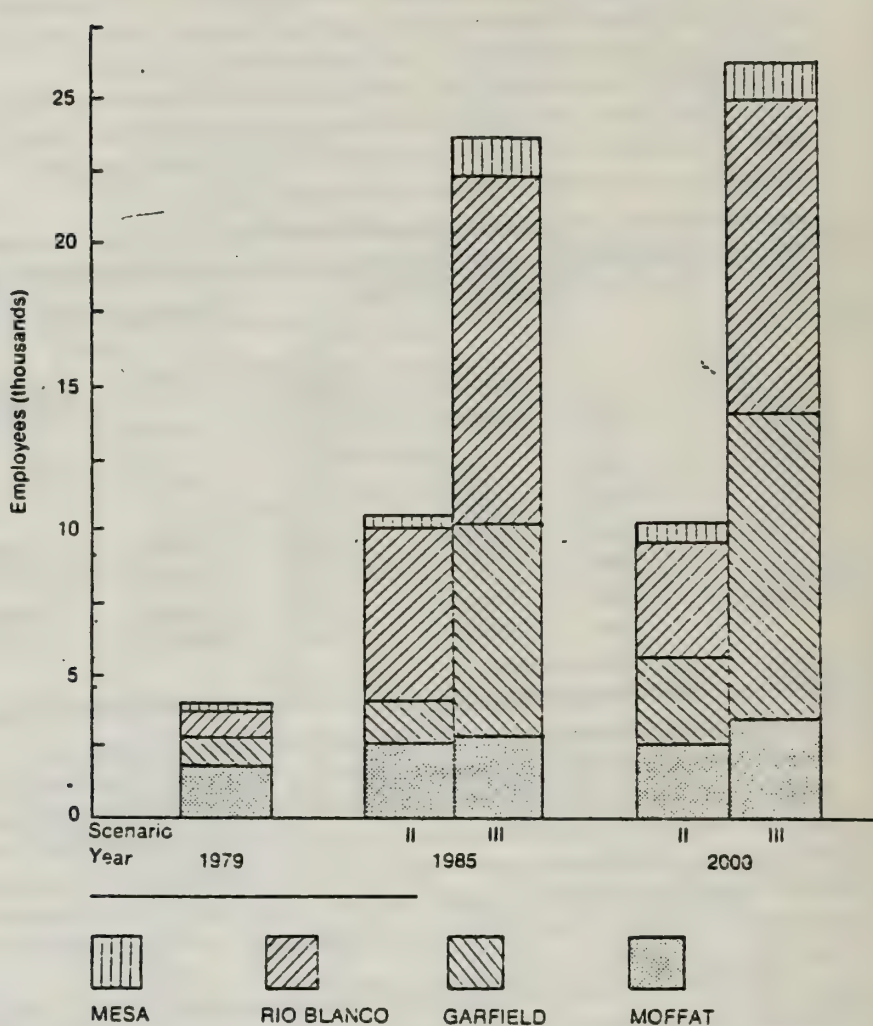
Table D Year 2000 Population Projections

County	Scenario I	Scenario II	Scenario III
Moffat	17.000	23 000	28.000
Rio Blanco	7.000	18.000	44.000
Garfield	41.000	62.000	95.000
Mesa	161.000	170.000	190.000
Total	226 000	273.000	358.000

Alternative Settlement Patterns

Both Scenarios II and III imply very rapid growth in specific areas of the region. This is particularly true for the 1979-1985 period. Table E notes representative examples of the percentage increases in population growth projected to occur between 1979 and 1985 in communities and areas of the region.

Figure 21 Basic Energy Worker Estimates Scenarios II & III



Source: CWACOG ("High Base Case")
& Bowers Chamoliss

Table E Projected Population Change by Community 1979-1985

	1979 Base Population	Scenario I Change	Scenario II Change	Scenario III Change
Craig	7.000	7%	76%	93%
Moffat County	10.925	2%	58%	73%
Meeker	2.250	-7%	348%	731%
Rangely	1.900	12%	302%	735%
Rio Blanco County	5.580	4%	257%	626%
Glenwood Springs	4.300	36%	68%	68%
Rifle and Rifle Fringe	4.727	7%	230%	471%
Grand Valley and Grand Valley Fringe	958	28%	100%	853%
Garfield County	22.000	22%	98%	204%
Debeque and Debeque Fringe	454	37%	54%	476%
Grand Junction	28.000	37%	50%	93%
Mesa County	75 000	35%	44%	71%
Total Four-County Region	113.505	28%	67%	124%

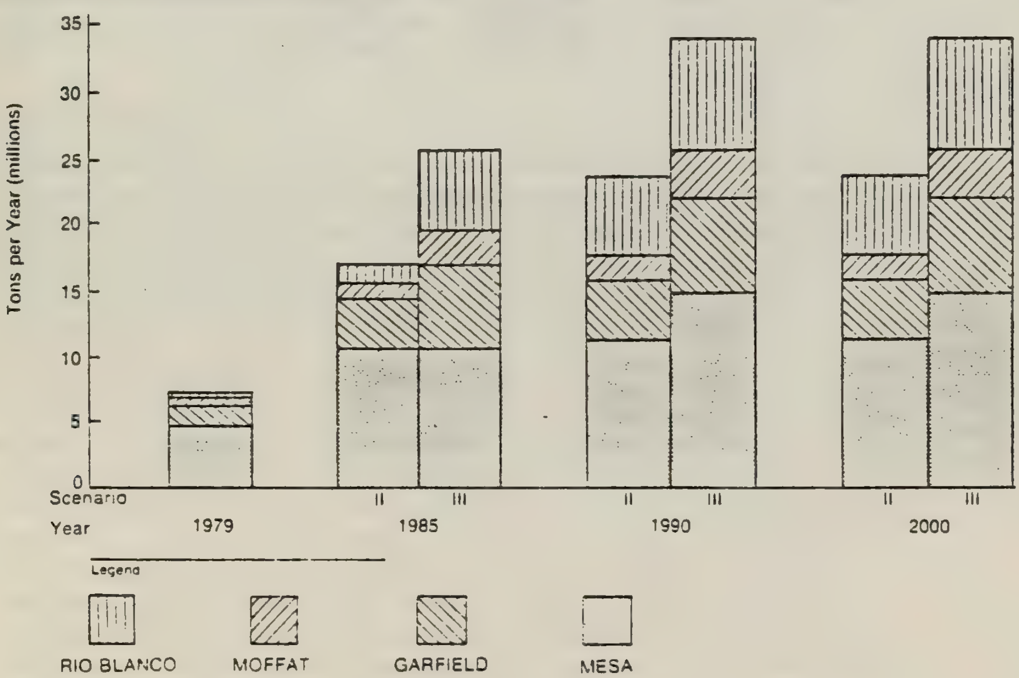
The question should be raised as to whether some of these extreme growth increases can be accommodated without destroying the particular community experiencing the growth. Can such communities as Meeker, Rangely, Rifle and Grand Valley physically accommodate such rapid growth? It is quite possible that some of the communities should not or will not be able to grow as fast as estimated. Problems created by such rapid growth may make the impacted community a less desirable place to live. thereby providing a strong reason for people to live elsewhere.

Product Estimates

Along with determining the travel needs resulting from population and employment growth in the region, estimates of the amount of products resulting from energy development activities were formulated. These estimates were primarily based upon information obtained from numerous environmental impact studies and statements. Product estimates were formulated for both Scenarios II and III.

Estimated coal and oil shale production are shown by County on Figures 22 and 23 for both Scenarios II and III. Oil shale production is projected to grow steadily through the year 2000. Coal production is expected to peak by 1990. However, there is substantial uncertainty as to the level of coal mining in the region by the year 2000 and thereafter. Though not shown on these figures, oil shale by-products and uranium shipments were included in the travel projection. These product estimates were utilized not only for employment estimates but also for estimating product haul requirements.

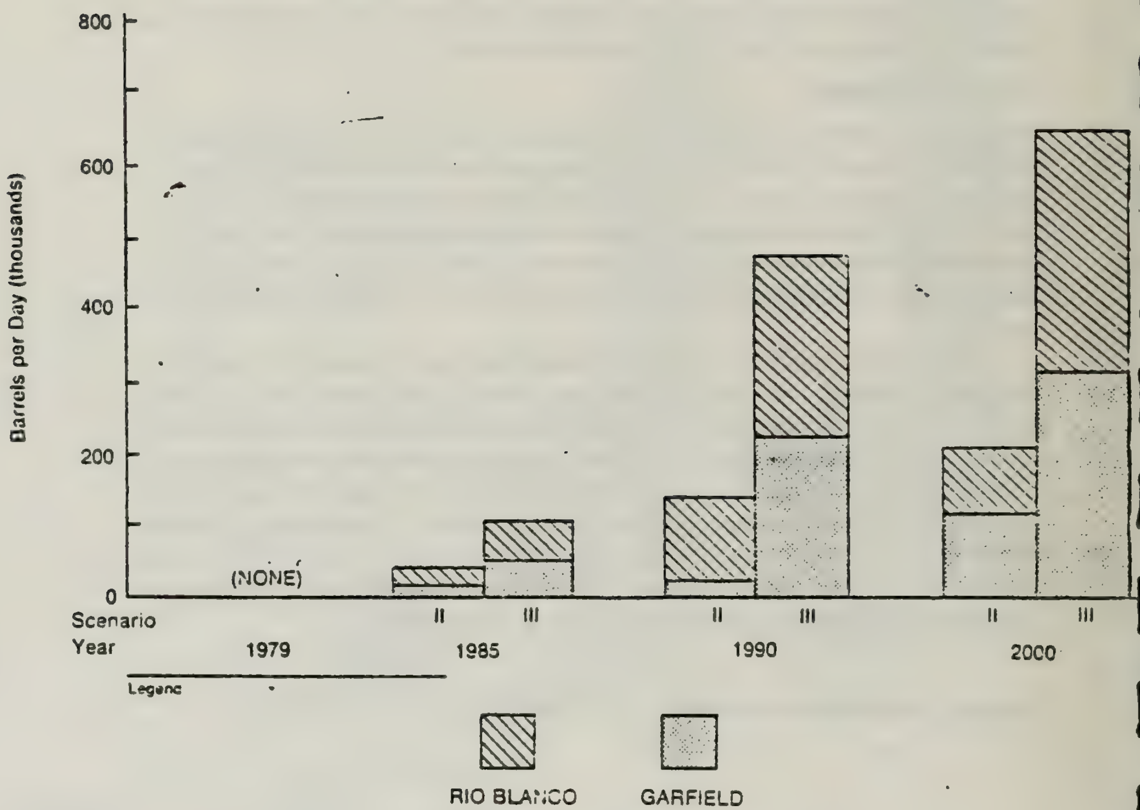
Figure 22 Estimated Future Coal Production



(Note all Garfield County projections include Anschutz and MidContinent Coal Basin Mines in Pitkin County)

Source Bowers Chambliss

Figure 23 Estimated Future Oil Shale Production



Source: TDA

4 Tomorrow's Travel Needs

This chapter discusses the future travel needs of the region through the year 2000. It is based primarily on the population and employment growth projected in Scenario II of the previous chapter. This scenario is used because it is a "mid-range" and represents a more likely set of events than either of the extremes. The latter sections of this chapter will separately treat the impact of the lower and higher Scenarios I and III.

In both growth projections and assumptions about the transportation network, this chapter seeks to describe and evaluate a mid-range, reasonable future. Therefore, a reasonable future system of people and goods movement has been assumed. This approach was chosen over the alternative of loading future travel demands on only the existing system. To assume major energy development with no change in the transportation system would be so unrealistic as to make the results of only academic interest. The effect of *different* assumptions about the transportation systems will be discussed in Chapter 5.

Transportation Assumptions

In addition to the assumptions of the Scenario II population and employment projections as described in Chapter 3, certain changes have been assumed to occur in the transportation network. These are:

People Transport.

No revolution in the mode of personal transportation was assumed. Personal travel will continue to be handled primarily by personal vehicles. The one exception is that extensive use of transit and vanpools for home to energy-site development was assumed. Transit would take the form of special buses such as those now run by Occidental Oil Shale from Rifle and Meeker to Tract Cb.

Transportation of Shale Products.

In general, it was assumed that the crude oil products from oil shale would move by pipeline because of the long-term economic advantages of pipelines. However, it was assumed that during initial operations products would be hauled by truck, either out of the study area or to a reasonable railhead. It was assumed that these product movements would switch from truck to pipeline as soon as a plant reached 15,000 barrels per day or by January 1, 1986, whichever comes last. (The reason for this 1986 date relates to use of the years 1985, 1990 and 2000 as comparison years. By leaving the oil in trucks through the year 1985, the impact of major product movements by truck can be illustrated). It should be noted that the pipeline construction could be delayed by the complexities of permit approval and leasing. Oil-shale by-products (nahcolite, soda ash, and alumina)

would move by truck, until rail facilities were available (see Rail System, following).

Coal Transport.

In general, it was assumed that coal would move by rail because of the high long-term costs of truck transportation. Therefore, we have assumed that those coal sites on rail will load directly into rail cars (unit trains, if the output is high enough) or, for those not directly served by rail, the coal will be transported by truck or conveyor to th nearest railhead. New or improved railheads (coal tipples) were assumed to be developed at several locations (Loma, South Canyon)

Highway System.

Because one of the major objectives of this study was to identify specific highway needs resulting from energy development, the existing highway system plus those improvements that have already been programmed was assumed. The programmed improvements in the Highway Department's five-year program were described previously.

Rail System.

A D&RGW spur from Craig to COLOWYO mine has been completed in 1979. Currently, the D&RGW is proceeding with the provision of a spur line west from Craig towards Lay which is assumed herein to be completed before 1985.

Because of the high projected volume of shale by-products from the Superior site, it is recommended, and thus assumed, that rail be extended to Superior by 1990. Depending upon if, where, and w other resources are developed in northern Rio Blanco County (for example, Consolidation Coal in Scenario III), staged construction of this line prior to 1990 may be evidenced. As with pipelines, the complexity of the permit and right-of-way acquisition process can delay these extensions. However, the COLOWYO extension was completed in approximately five years from beginning of feasibility study to operation.

Pipeline and Electrical Transmission Lines.

Pipeline development was assumed to follow the assumptions described above under "Shale" but no attempt was made to define specific locations. Electrical transmission lines were in the private sector, and were assumed not to alter person or product movements.

Gas and Oil Transport.

It was assumed that all gas and crude oil from wells would be transported by pipelines.

Transport of Other Commodities (Uranium, Vanadium and Limestone).

Raw materials and products would continue to move by truck to destinations or to nearby railheads. However, the truck volumes are small compared to those for other commodities.

Air System.

Continued development of the existing airports and system was assumed. No revolutionary changes in the relative importance of air travel was assumed, however, and therefore air travel continues as a specialized, high value service for a relatively small part of the total

market. The major travel needs of the four counties relate to home-to-work and other resident travel and to the transportation of products and commodities. The air system was not assumed to be a major factor in fulfilling these particular needs.

Coal Liquefaction.

Coal liquefaction was not included in Scenario II, but is discussed as a possibility in Chapter 5. The resulting liquid or gas products would be expected to move by pipeline.

Projected Travel Needs

As mentioned previously, the projected travel needs are based on the mid-range projection of population, employment and energy development and the transportation system assumptions listed above. This section describes the results of a test of these assumptions. The tests were done by a computer-based process — TDA/TANDEM — adapted to the needs of this project. Through this process, travel demand was derived from population, employment and product projections and loaded onto individual segments of the roadway and rail systems. Because of their significantly differing scales and characteristics, regional needs are considered separately from needs within the cities. Analysis was conducted for the time periods 1985, 1990 and 2000; but this summary report highlights the evaluation at 1985 and the year 2000. Inclusion of 1990 would have added little additional information. (Full technical documentation is available in the Technical Notebook).

Regional Needs.

Considered herein are the needs of the regional highway, rail, air and pipeline systems.

1 Highway.

Figures 24 and 25 illustrate the projected daily travel volumes and compares them with existing traffic volumes. In general, the regional intercity highway volumes increase substantially by the year 2000. Much of this increase is projected to happen by 1985.

Figure 26 shows the estimates of loaded energy-product and construction trucks. The estimated movements of construction materials and equipment were small — on the order of 20 heavy trucks per day to an oil shale site at the peak of its construction period — compared to later product shipments. Due to the product movement and energy site construction assumptions, truck volumes are significantly higher in 1985 than in 2000. In numbers, these trucks are a relatively small part of the total daily traffic (one to twelve percent). However, their importance is disproportionate to their number. Because of size and speed characteristics, their impact on roadway capacity is much greater than that of smaller vehicles. This is particularly a concern on sections of roadway with significant grade. Because of weight, their impact on the structural life of paved surfaces is also much greater. That is because one repetition of a single heavy axle load is equivalent to several thousand repetitions of automobile or light truck loads. In developing estimates of future highway needs, a special analysis considered the effect of these heavy axle load repetitions on roadway life.

Figure 27 shows roadway accident rates for 1977 by link, and highlights the high accident rate locations.

Figures 28 and 29 summarize future highway needs based on considerations of traffic volumes, structural loadings, and safety problems. It should be noted that many of these improvements are needed regardless of energy development. This will be discussed later in this chapter.

2 Rail.

Table F illustrates the rail car loadings of Colorado West coal estimated for 1979 and projected for years 1985 and 2000. To offer a perspective, current (1978) utilization of the D&RGW "Colorado River" line is 27 million annual gross tons (all products combined) on each mile of road, and of the "Craig" line is 8 million annual gross tons.

Table F Projected Rail Volume of Colorado West Coal

	Annual Tons of Coal (millions)		Annual Carloads (thousands)	
Year	**Craig Line**	**Colo. River Line**	**Craig Line**	**Colo. River Line**
1979 (Est.)	2.8	2.5	28	25
1985 (Proj.)	10.0	4.9	100	49
2000 (Proj.)	10.7	5.6	107	56

Source: TDA

Nearly all of the projected coal volumes could be reasonably expected to move in unit trains and the remainder in multiple car lots. Based on probable markets for Colorado coal, it is reasonable to assume that the bulk of this tonnage will move to the east out of the study area and either through the Moffat Tunnel or over Tennessee Pass. There have been concerns expressed over the capacity of th D&RGW lines to handle the major traffic increases of energy development. It does appear that if no improvements were made to the lines, future capacity could be a problem. However, improvements in traffic control, the addition of passing sidings, use of heavier rails and other actions can boost capacity from present levels. Based on review of other studies and on discussions with railroad officials and specialists, it has been concluded that under reasonable assumptions on rail improvements, rail capacity will not be a problem in serving the region's energy development.

3 Air System.

Airport development needs fall into two general categories — fundamental development and capacity development. Fundamental development is based on providing basic facilities for handling the *type* of aircraft expected to use an airport over the next five to ten years. Actual passenger and aircraft volumes are not critical factors, except for meeting certain minimum threshhold values. Capacity development, on the other hand, is a function of the passenger and aircraft *volumes* as well as the critical aircraft type and aircraft mix. Capacity development, especially on the airside (e.g. multiple runway systems), usually occurs only at large metropolitan area airports.

Development needs for the airports at Grand Junction, Hayden, Rifle, Rangely, and Meeker are based on the needs identified in the respective airport master plan reports. The needs for Aspen's Sardy Field are primarily related to serving demands located outside of this study area and are not addressed further in this report.

In general, the needs at the six selected study area airports fall into the fundamental development category on the airside and

Figure 24 — Existing and Estimated Year 1985 Traffic Volumes (Scenario II)

TDA Transportation Development Associates Inc. Boulder Seattle

Figure 25 Existing and Estimated Year 2000 Traffic Volumes (Scenario II)

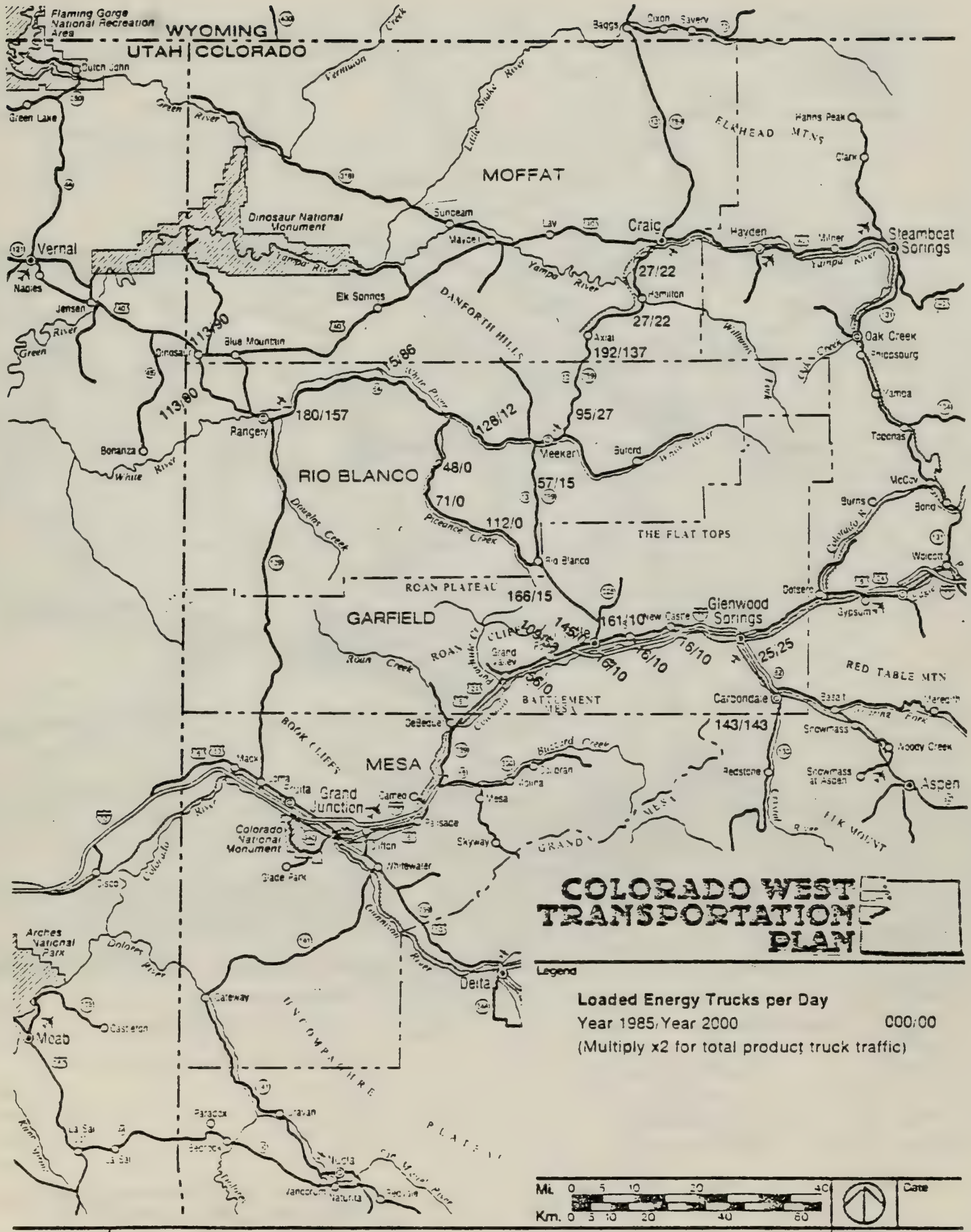


Figure 26 Year 1985 & 2000 Loaded Energy Trucks (Scenario II)

TDA

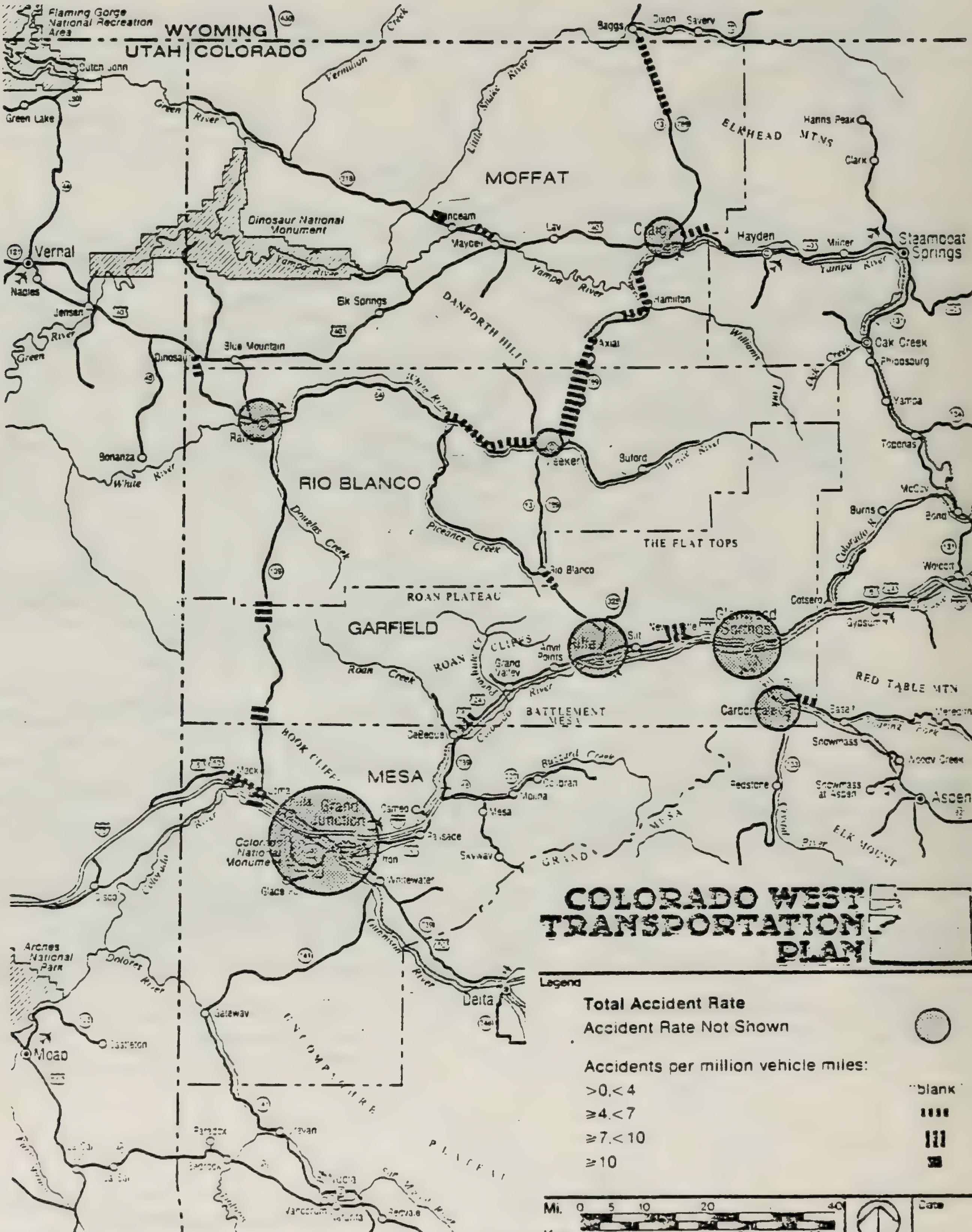


Figure 27 Total Accident Rate Per Million Vehicle Miles (1977 Data)

TDA

Figure 28 Highway Needs 1980-1985

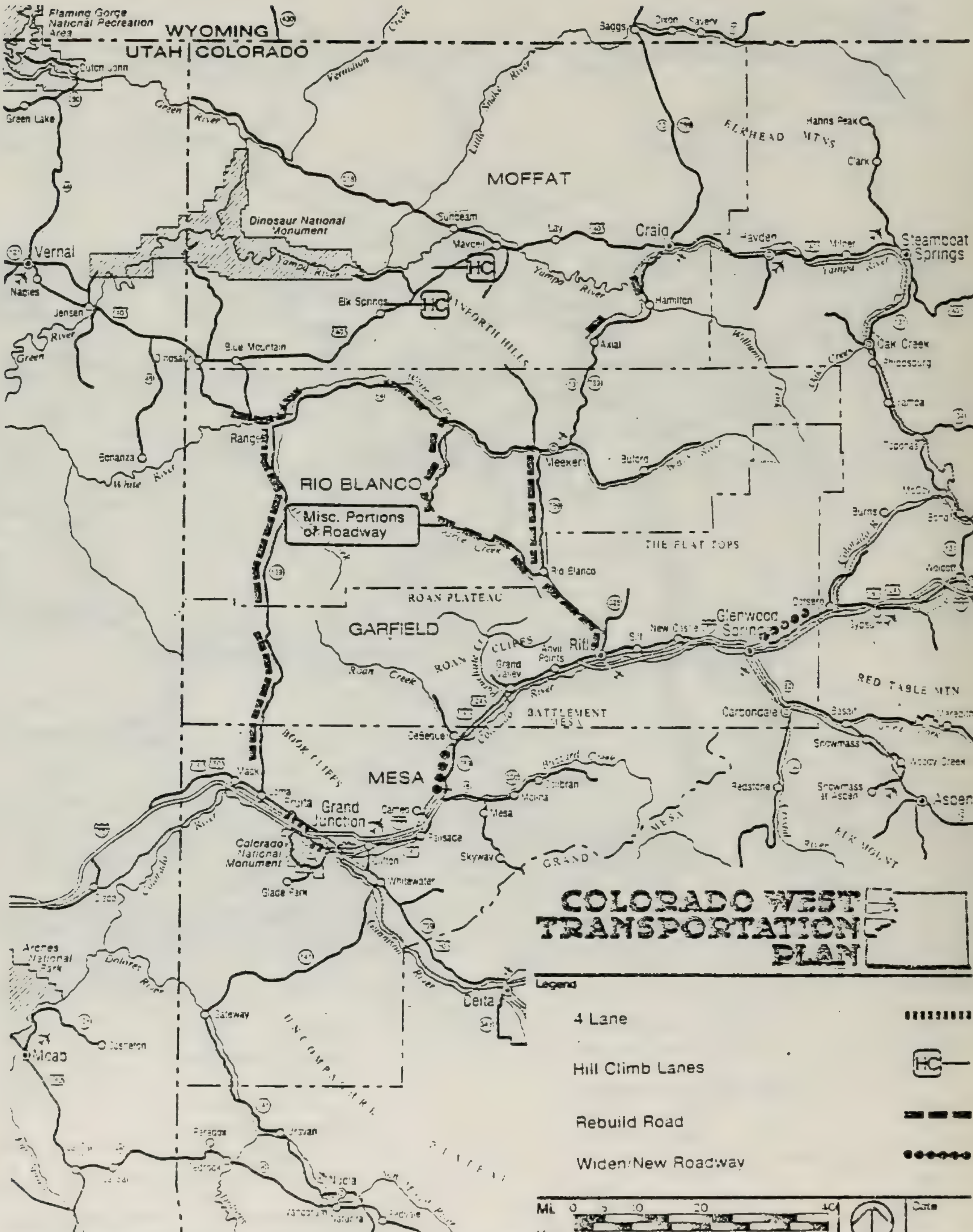


Figure 29 Additional Major Highway Needs 1986-2000 (Overlays Not Included)

landside, with the notable exception of Grand Junction's new passenger terminal construction, which is a landside capacity item. The key needs at these six airports are expanded below.

- Walker Field, Grand Junction — Key Needs and Deficiencies
The existing terminal complex (includes terminal building, air carrier aircraft parking apron, and auto parking) is inadequate to accomodate the ever increasing passenger and aircraft volumes. A new 45,000 square foot terminal building, apron space for five aircraft parking positions, and auto parking for 500 cars are necessary to serve the passenger and aircraft needs. The primary runway 11/29, the taxiway, and apron need to be overlayed. The parallel taxiway to runway 11/29 was recently extended to full runway length.
- Yampa Valley Airport, Hayden — Key Needs and Deficiencies
The Hayden airport is currently in need of apron, taxiway, and runway improvements such as widening and overlays. Land is needed for clear zone protection and future terminal area expansion. An extension and overlay of the runway will be needed to serve heavier air carrier aircraft in the B-737 category. The Hayden airport also lacks a parallel taxiway.
- Garfield County Airport, Rifle — Key Needs and Deficiencies
The Rifle airport needs to be developed to Basic Transport (BT) standards in order to serve business jets and possible air carrier service using Convair 580 aircraft. Energy development will create demand for air commuter service as well. A new 7,200 foot runway and parallel taxiway are needed to replace the existing 5,155 foot runway, which is length-constrained by the terrain.
- Rangely Airport, Rangely — Key Needs and Deficiencies
The existing runways are of insufficient length to safely accomodate many of the larger business aircraft which presently use the airport. The primary runway and parallel taxiway should be extended to 6,700 feet to serve them. Using business jet aircraft as the critical aircraft type places the design standards in the Basic Transport (BT) category. Air commuter service is likely to be attracted to the Rangely Airport as energy development continues.
- Meeker Airport, Meeker — Key Needs and Deficiencies
Meeker's 4,500 foot runway is not sufficient to safely handle business jet activity and the possible commuter service that might be attracted by the energy development. Meeker also lacks a parallel taxiway. A runway extension to 6,500 feet and construction of a full length parallel taxiway are needed to serve these aircraft activities. Topographic constraints prevent the future installation of a conventional precision instrument landing system (ILS). A microwave landing system (MLS) could be installed for commuter service use. The design category for the Meeker Airport is Basic Transport (BT) because of the business jet activity.
- Craig - Moffat County Airport, Craig — Key Needs and Deficiencies
Craig has commuter service at this time, but its 5,000 foot runway is not adequate to safely handle the larger business aircraft. The runway needs to be lengthened and strengthened, and a parallel taxiway should be constructed. The development category for the Craig Airport is Basic Transport (BT) because of the business jet activity.

4 Pipeline.

The implication of the previous assumptions on movement of the oil from oil shale is shown in Table G. The table shows the number of pipelines that would theoretically be required based on various pipeline sizes. At one extreme, all of the crude projected for year 2000 could theoretically flow in one single 20" pipeline. However, this assumes that the crude could be assembled economically from the various development sites into that single pipeline and that it could all be shipped out of the region in one direction. In fact, the pattern will be much more complex because it will depend on the markets, the refinery capabilities for individual producers, and the available capacity of existing trunk pipelines serving the major markets.

Table G Additional Pipeline Needs Resulting From Shale Development (Scenario II)

(Theoretical Number of Pipelines of Specific Diameter)

Year	Barrels per Day	12"	16"	20"
1985	42,000	1	1	1
1990	140,000	3	2	1
2000	205,000	4	2	1

Source: TDA

Travel in Cities and Towns

The primary focus of this study is on regional transportation problems and not on detailed transportation needs within communities. To a great extent, this focus is due to differing philosophies regarding developing land use patterns currently evidenced throughout the region. The most pertinent examples of these differences in land use patterns are Rio Blanco County, where 80% of the population has historically concentrated in the municipalities, and Mesa County, where 60% of the population growth occurs outside municipalities. The effects of these differing philosophies is felt to a much greater extent on the local roadway and street network than on the regional network.

Even at the level of detail this study addresses, there are several general findings which have applicability to almost all the communities in the region. One is of major importance. As the communities in the region begin to grow towards the population estimates of Table D, consideration should be given to community planning efforts which encourage the realization of a land use pattern which minimizes sprawl and the resulting inefficient use of the automobile. Such patterns offer not only the opportunity to reduce the number of or shorten the length of local trips, but also the opportunity to divert some of these trips to other modes, like walking, cycling, and transit. The benefits of such patterns are not only economic — for the public sector, reduction in the costs of providing and maintaining a significantly increased transportation infrastructure; for the private sector, reduction in transportation-related costs of fuel, etc. — but are environmental as well — less pollution, noise, etc. Also, efficient land use development is better able to match growing needs for services, including transportation, with growing population than poorly-planned "boom-town" patterns.

Two other general findings should also be recognized:

1 At the Scenario II level of population growth most communities will be strongly impacted by regional traffic going through them. Additionally, many communities will be subjected to significant increases in energy-related truck traffic. As a result there will be growing interest in obtaining funding for and constructing by-passes in these communities. At the Scenario III level of growth the need for community bypass routes becomes even greater.

2 The emphasis on getting products off of highways and onto the rail lines will result in substantial increases in rail traffic in the region. In turn, this will result in problems being created where major urban streets cross such railroads at grade. In addition, rail extensions (for example, south to Superior) will likely create new grade crossing problems. For community safety and unity reasons, steps need to be taken to analyze the existing and projected grade crossing problems in the urbanizing areas of the region and develop an active plan to construct needed grade separations or crossing improvements. Additional problems related to increased rail usage include the restriction and/or isolation of access to land, as is evidenced in the Roaring Fork Valley, and the potential for vehicular circulation problems in towns due to limitations on the number of rail crossing points.

Impact of Low and High Scenarios

The previous discussion was based on the "most-likely" energy development condition, Scenario II. This section discusses the major differences that would result from actual events being more like the lower Scenario I (no energy development) or the higher Scenario III (maximum feasible energy development).

As a prelude to this discussion, it is necessary to examine in greater detail the future highway needs shown in Figures 28 and 29. To a large extent, these needs are predicated on the existing condition of the study area roadway network. Based on the *1977 State Highway Sufficiency Rating and Needs Study*, and on definitions contained in the *1977 Colorado Annual Highway Report*, Figure 30 details roadway segments that are rated as "less than fair." Table H compares the study area roadways to the State roadways as a whole. Even with I-70 completed, a large number of "critically insufficient" study area roadways will still exist.

In addition to highway needs related to "sufficiency" problems, the methodology used in deriving the future highway needs for Scenario II addressed other "critical" concerns. These include high-accident locations, sharp curves, narrow roadway cross sections, and other "critical" links as defined by the District III Engineer. All of these concerns are related to current deficiencies.

Table H 1977 Sufficiency Rating Comparison ("Rural" Roadways)

Ratings	Percentage of Total Route Miles		
	Study Area		State as a Whole
	Excluding I-70 Travel Way	Including I-70 Travel Way	
Unsatisfactory	9	13	11
Critical	47	42	28

and as such, the need for improvements is somewhat independent of traffic volumes. For example, the need to widen a 20 foot roadway or to improve a sharp, unbanked curve may exist whether 500 or 5000 cars a day use the roadway. However, traffic volume impacts the type (or scope) and timing of the needed improvements. If two roadways have similar deficiencies, improvements to the one with higher traffic volumes will usually have a higher priority.

Scenario I (Trend Population/Employment Growth)

Under this Scenario, population and employment continue on a "trend" basis, and the rate of roadway improvement would be slow. Even though roadway needs exist now, the traffic volume and accident exposure are relatively low. Improvements would probably be targeted on specific problem locations. Roads that would require less extensive improvements under Scenario I than Scenario II include State Highways 6 (near Rifle), 13, 40, and 64, and the Piceance Creek Road.

Public transportation would be much as it is today, with some elderly and handicapped service improvements. The limited experimental shale products there would be moved by truck. Coal would generally move to the nearest railhead, by truck or possibly conveyor, but there would not likely be any rail extensions.

Scenario III (High Projections)

For this projection, there were certain modifications to the Scenario II transportation network. As in Scenario II it was assumed that there would be emphasis on transit and vanpool programs for energy-related home-to-work trips. However, because of the major national commitment implied by this high projection, it was assumed that shale product pipeline(s) would be expedited, resulting in their completion shortly after the beginning of pilot production. Scenario III changes the expected level of coal production significantly in a few locations. Associated with these changes are the assumptions that a rail extension from Loma to the Mesa/Garfield County Line to serve the Sheridan mines would be built by about 1990, and that the rail extension linked to Superior (as discussed in Scenario II) would directly serve the coal mines along State Highway 13 by 1987, and later extend on to Superior.

Figure 31 illustrates the highway loadings under the Scenario III projection and the transportation system assumptions. Traffic volumes under this Scenario are about 15 percent higher than in Scenario II. The highway needs are approximately one-third higher. Specifically, improvements to provide four-lane roadways would be required on State Highways 6 (vicinity of Rifle), 13 (from Rifle to Buford turn-off north of Meeker), and 64 (from Rangely east to Moon Lake power plant, which was assumed in this scenario). Nine hill-climbing lanes in addition to those detailed in Scenario II would be needed, principally on Highways 6, 13, 40 and 64. Overlay needs would be increased nearly 20 percent, primarily on Highways 6, 13, 40, 64, 70, 139, and Piceance Creek Road. Additionally, the higher traffic volumes of this scenario would accelerate the need to correct existing deficiences. The highway needs under this scenario are for "people travel" related to the large projected population and employment growth because it is assumed that non-highway modes

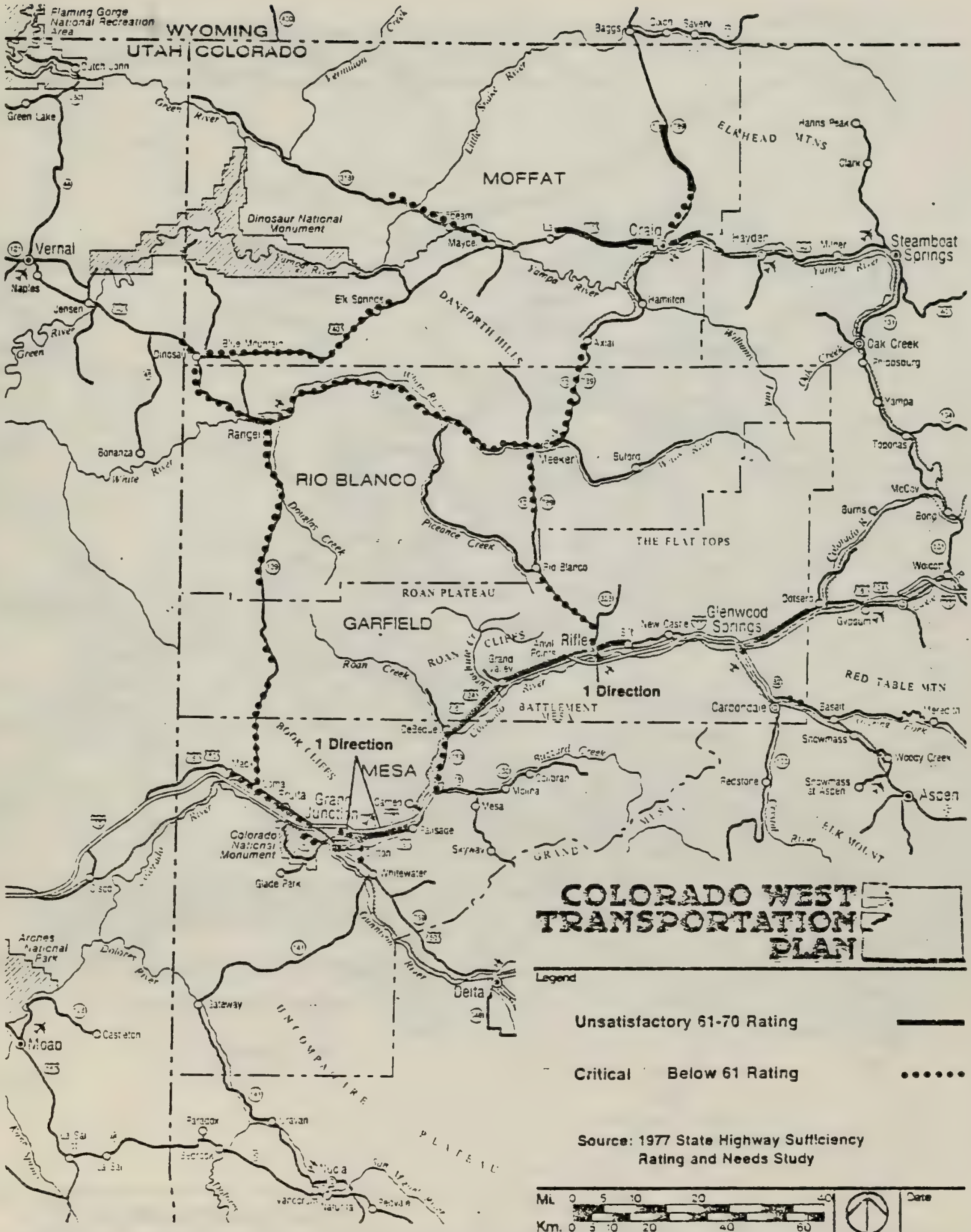


Figure 30 Roadway Sufficiency, 1977, Rated as Worse Than Fair

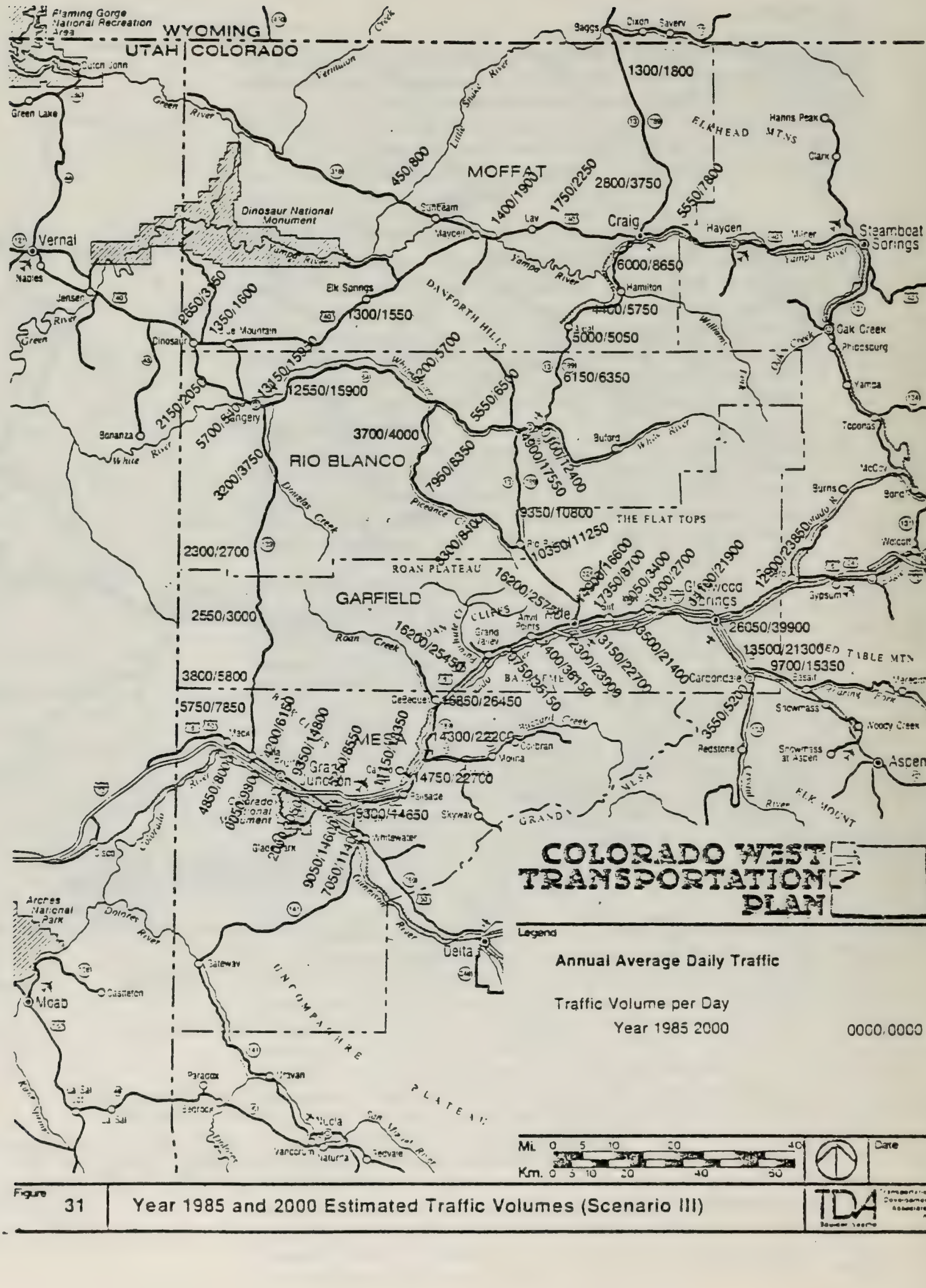


Figure 31 Year 1985 and 2000 Estimated Traffic Volumes (Scenario III)

for products would be expedited. Implications of variations of these product movement assumptions are discussed in Chapter 5.

In general, there were no significant changes to other elements of the system.

5 Transportation Alternatives

Chapter 4 was based on reasonable assumptions of the transportation system that would exist at various stages of energy development. This chapter discusses variations of those highway, transit, rail, pipeline and air transportation assumptions. Finally it discusses the probable impact of these variations.

Highway

While the existing highway network may require some rebuilding and widening, it generally provides a reasonable pattern of connections within the four-county region. The possible need for additional highway access into the Piceance Creek Basin is a potential exception. A number of alternatives have been proposed in the past. This study looked at a series of alternative routes into the area and assessed their relationship to developing energy sites and their possible impact on the other links of the roadway system. This analysis is detailed in the "Piceance Creek Roadway Report" contained in the technical notebook. Many routes were rejected as being physically too difficult to build. Figure 32 shows the candidate routes which do appear to be physically feasible.

In general, the Piceance Basin alternatives appeared to have no major impact on traffic volumes on the existing highway network. Because of the grades and the winding alignment, travel time savings were small and therefore traffic diversion from existing routes was generally limited. However, the Ca-Rangely route and, to a lesser extent, the Cb-DeBeque route have the potential to serve important home-to-work and energy-site development related trips. These two roadways could be considered as the top priorities in the development of a plan for improved access into this area.

The roadway impacts of developing a Synfuels (coal liquefaction) plant either south of or west of Craig was also investigated as an alternative. Due to labor intensiveness of such plants, major additional traffic volume demands were projected. However, because the plant would be in relatively close proximity to Craig, major impacts on the primary roadway system would be limited to the Craig vicinity.

Transit

The traffic estimates described in the previous chapter were based on a reasonably aggressive transit program for the home-to-work trip. There are of course alternatives of doing either more or less with transit.

A minimum transit program would provide little more than limited service for elderly and handicapped and would not provide specific programs for the home to energy site work trip. Under these conditions, there would be no vanpools, the companies would not provide bus service, and the bulk of travel would be by automobile at a typical average occupancy of 1.5 to 2.0 persons per vehicle for

work trips. Figure 33 illustrates the percentage increase in daily tr on those highway links leading to energy sites resulting from this minimum transit program. Capacity problems that could necessitate significant roadway improvements (four-laning) would be required in the following locations:

- Colorado 64 west of its junction with Colorado 13.
- Colorado 13 south of Craig,
- Colorado 13 south of Rio Blanco, and
- The Piceance Creek Road.

A more aggressive transit program would, in addition to those items discussed in Chapter 4, develop internal transit systems in the communities of Grand Junction—Fruita—Palisade, Glenwood Springs, Rifle, Rangely, Meeker and Craig. These systems could theoretically serve work trips to places of employment within the communities and other non-work trips such as personal business, shopping and social. From a regional standpoint the impact on overall travel demand would probably be small. History elsewhere in similar communities would suggest that the transit programs would attract less than five percent of total trips. While more detailed study of each of the local situations might show social and economic justification for providing such systems in any case, even a five percent diversion to transit would have little impact on the overall roadway problems previously described.

Rail

The results of Chapter 4 were based on an assumed extension of rail south to the Superior site by 1990. Figure 34 illustrates energy truck volumes if this rail spur is not constructed. If not extended, all of the products would have to move by truck from Superior to the nearest railhead. As a result, the large energy truck volumes experienced in 1985 (see Figure 31) would be continued to year 2000, increasing the wear on the roadways and further impacting the towns of Meeker, Rangely, and Rifle.

Figure 35 shows energy truck volumes for Scenario III assuming that rail extensions south to Superior and north from Loma are not constructed. As in Scenario II, products would have to be trucked to the nearest railheads. This added truck traffic will increase roadway wear, and will further impact the towns of Meeker, Rifle, and Loma. Additionally, that truck traffic coupled with increasing traffic volumes will further exacerbate problems on Colorado 13, and may necessitate a higher level of improvement of portions of that roadway than discussed previously.

Pipeline

Coal.

Initial consideration was given to the possibility of coal slurry pipelines serving this area. However, this was rejected because the economics of coal slurry pipelines require annual volumes in the neighborhood of 8 to 10 million tons shipped from one area to a market. While the total output of this four-county study area is already about 7 million tons per year and will grow to more than double that by 1985, its markets are generally widely scattered. Economic justification of the pipeline depends upon having a single

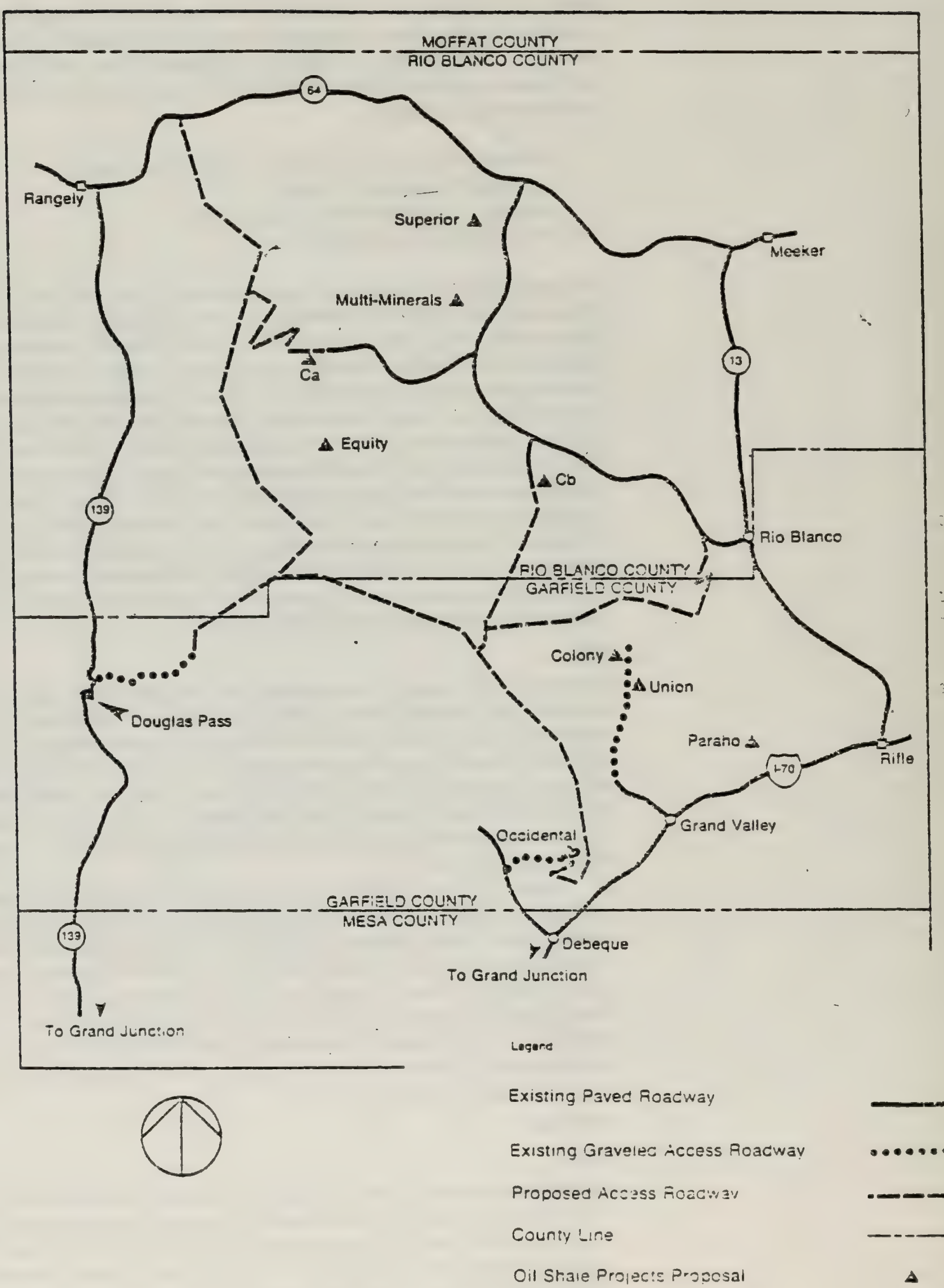

MOFFAT COUNTY
RIO BLANCO COUNTY
64
Rangely
Superior
Meeker
Multi-Minerals
13
Ca
Equity
Cb
139
Rio Blanco
RIO BLANCO COUNTY
GARFIELD COUNTY
Colony
Union
Douglas Pass
Paraho
I-70
Rifle
Grand Valley
Occidental
GARFIELD COUNTY
MESA COUNTY
139
Debeque
To Grand Junction
To Grand Junction
Legend
Existing Paved Roadway
Existing Graveled Access Roadway
Proposed Access Roadway
County Line
Oil Shale Projects Proposal

Figure 33 Percentage Increase in Daily Trips Resulting From Minimum Transit Program

Figure 34 Year 2000 Loaded Energy Trucks (Scenario II)-Links Impacted Assuming No Rail Extension

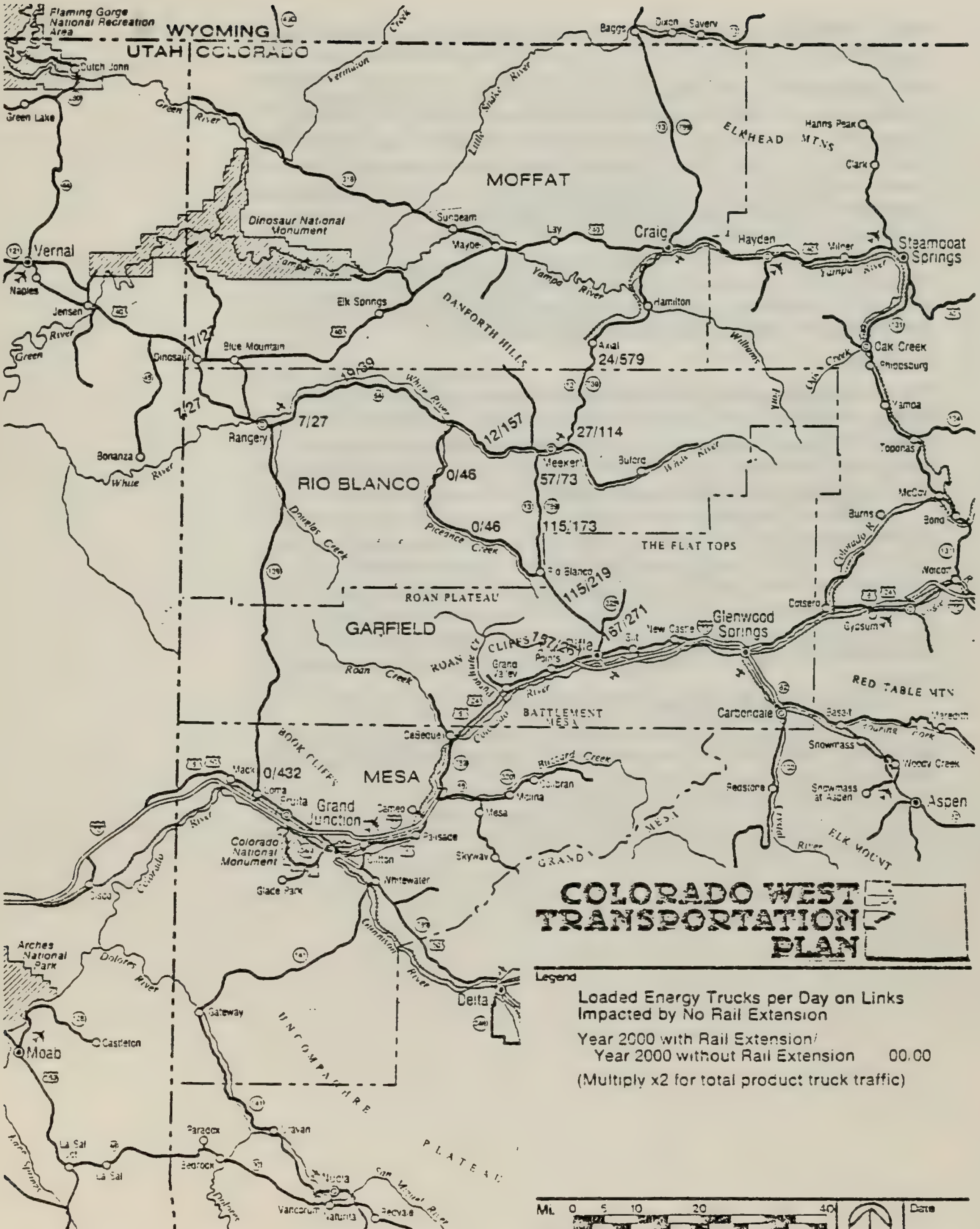


Figure 35 Year 2000 Loaded Energy Trucks (Scenario III)-Links Impacted Assuming No Rail Extension

TDA

major market that can afford to purchase the capacity of a pipeline.

Shale Oil.

If the assumptions of Scenario II and III on shipment of shale oil by pipeline are not borne out actual events, there would be a potential impact of as many as 290 additional loaded trucks per day per *site*. In the Scenario II level of development, this would add nearly 1,100 loaded trucks daily in year 2000; in the Scenario III level, this figure approaches 3,700 loaded trucks daily. The impacts of *no* pipeline construction are far more severe than any of the other modal alternatives, specifically in terms of impact on pavement life, roadway capacity, and of community impacts. This coupled with the economics of product movement indicates that construction of no pipelines is not only undesireable, it is also unlikely.

Air System

The principal airport development alternatives considered here were those presented in the individual airport master plan reports. While these planning efforts have, in general, addressed the impact of energy development, future review and update of the master plans will be necessary to adequately respond to the energy issues.

Additional consideration was given to the construction of an air carrier airport near Carbondale, Garfield County, as a replacement for Aspen's terrain-constrained Sardy Field. The Carbondale replacement airport was first investigated by the FAA in the late 1960's. No local agency has shown an interest in sponsoring this project as there appears to be no compelling justification for the facility. Table I presents a status summary of the Carbondale airport proposal.

Some consideration was given to expansion of air freight services to the region because of energy development. However, the economics of air freight compared to the available alternatives make major use of air shipment unlikely.

Table I Summary — Proposed Carbondale Air Carrier Airport

Subject: Proposed air carrier airport at Carbondale, Garfield County.

Proposed by: Federal Aviation Administration (FAA).

Date proposed: Circa 1969.

Purpose: To replace Sardy Field at Aspen, Pitkin County.

Rationale: Expansion of Sardy Field (current runway is 6,000 feet long) to handle larger aircraft is severely constrained by mountainous terrain.

Preliminary site selection criteria:
1. Proximity to town of Aspen.
2. Feasibility of constructing a primary runway of at least 10,000 feet in length.

Selected site (preliminary):
1. In Section 20 of Town 7s, Range 87w (runways extend into Sections 18 and 29).
2. Approximately 5 miles northeast of the town of Carbondale, Garfield County.
3. Approximately 25 miles northwest of the town of Aspen, Pitkin County.

Proposed runways:
1. Primary, 13/31, length = 10,000 to 12,000 feet.
2. Alternate, 18/36, length = 7,000 feet =.

Project status:
1. No action taken beyond FAA's preliminary site selection because no local agency has sponsored the project.
2. Some residential development has taken place near the selected site.

Project requirements:
1. A local sponsor is needed.
2. Land development issues must be addressed to avoid development which could inhibit facility establishment.

6 Recommendations

Previous chapters have described the needs for transportation system improvements. This chapter makes four kinds of study recommendations: those of overall policy; specific transportation system recommendations; recommendations summarized by responsible agency; and finally, a section on financial recommendations and considerations.

Policy Recommendations

Three study findings stand out as major policy concerns. These findings relate to how products move, a philosophy of finance and community impacts. Later sections of this chapter include recommendations for more specific actions.

Product Movements.

In the long run, economics will tend to force the products onto rail and pipeline systems. However, differences in the implementation schedules of plant development and those of the transportation links may result in hauling of products by truck during initial operations. Resulting truck volumes will be a significant problem on critical highway links and will pose major problems in the region's towns and cities.

Therefore, rail and pipeline systems should be available on a schedule consistent with the timing and magnitude of energy resource development. This can be controlled through the permitting process.

Finance.

Providing transportation facilities to serve the needs of energy development creates financing problems in at least two ways.

- The needs occur sooner than do the tax revenues that could pay for those needs.
- Some needs are directly and specifically related to the energy development and should be paid for with energy-related funds. For example, roadways built solely to serve energy development sites should not be paid for from general local and state highway funds.

The region should adopt an overall financing policy that recognizes these problems and establishes an equitable approach. This will be discussed in a later section of this chapter.

Community Impact.

This study focused on regional transportation problems and not on the internal transportation needs of the communities. However, study results make it clear that many of the transportation and other growth related problems are concentrated within urban areas.

As a key element in growth planning, the towns and cities need to determine the desired and feasible level of community growth and to develop the institutional capacity to accommodate sound growth. A key step in this process will be deciding the population and growth rate which the community can tolerate. Then, after these deliberations have been made, the cities should develop appropriate plans and strategies. Cities, towns and the counties should begin detailed preparations to make these determinations.

Summary of Transportation System Recommendations

The groundwork for system recommendations was laid in Chapters 4 and 5. This section will summarize the physical and operational systems needed for highways, transit, airports, rail, pipelines and electric transmission lines.

Highways

The estimated highway needs for Scenario II development are listed in Table J. These needs were developed based upon a link by link evaluation of the regional highway system. The evaluation included consideration of the following factors:

- safety/accident rates
- volume/capacity relationship
- roadway cross section
- grade
- curves
- pavement serviceability index
- width of existing bridges
- roadway adequacy assessments by District personnel.

These factors provide the basis for the recommended improvements. The projects listed, even if all completed, would not bring the entire regional network up to an "ideal" design standard. However, they do address the most needed improvements required to respond to energy development and current safety needs.

Also shown in Table J is the period in which the improvements should be completed, based upon what are now the expected schedules of development and on existing highway conditions. In many cases, the current condition of the region's highways are below Department of Highways standards by virtue of factors such as pavement deterioration and safety problems. However, energy development is the over-riding pressure for improvement. Without energy development, it is probable that only minimum improvements will be made within currently constrained funding. In other cases, needed improvements — hill climbing lanes, for example — are directly related to energy generated traffic volumes. The timing of these needs is based upon the expected rate and pattern of energy development for Scenario II. By monitoring future energy development and referring to Table J, adjustments in timing could be made for those projects related to energy development. As energy development occurs, the table should be reviewed and those energy related improvements be adjusted accordingly.

Between now and 1985 there are needs for about $75 million worth of regional highway improvements, based on Scenario II

Table J Recommended Roadway Improvement Needs

Route	From	To	County	Lane Miles	Project		1980	1981	1982	1983	1984	1985	1986-2000
							Annual Improvement Needs[1]						
US 6	Mack	I-70	Mesa	29.8	Overlays	Lane Miles		6.8	18.6	3.0			17.2
						$ x 1000		170	705	150			655
					4 Lane from	Route Miles							6.3
					I-70 to Fruita	$ x 1000							9450
US 6	Bus-70 west, in Grand Junction	Bus-70 east, in Grand Junction	Mesa	22.0	Overlays	Lane Miles				22.0			
						$ x 1000				1100			
US 6	I-70 west of Rifle	I-70 east of New Castle	Garfield	46.8	Overlays	Lane Miles		1.2	1.0	13.4	18.2	8.6	42.8
						$ x 1000		30	25	335	605	215	1460
C 13	I-70 south of Rifle	Garfield-Rio Blanco Co. Line	Garfield	36.2	Hill Climb Lane .4 mi.	$ x 1000		220					
					Safety Improvements	Route Miles							15.6
					(rebuild road)	$ x 1000							15600
					Overlays	Lane Miles		3.0	31.2	1.0		1.0	5.0
						$ x 1000		75	780	25		25	250
C 13	Garfield Rio Blanco Co. Line	Meeker	Rio Blanco	52.4	Safety Improvements	Route Miles		2.0					20.1
					(rebuild road)	$ x 1000		2000					15075
					Overlays	Route Miles		4.0	22.6	21.8			48.4
						$ x 1000		100	565	545			1415
C 13	Meeker	Rio Blanco-Moffat Co. Line	Rio Blanco	32.2	Overlays	Lane Miles	11.4	(In Long Bill Budget)					
						$ x 1000	522						
					Overlays	Lane Miles		18.2	2.6			11.4	20.8
						$ x 1000		455	65			570	1040
C 13	Moffat Rio Blanco Co. Line	Craig	Moffat	60.6	Overlays	Lane Miles	11.2	(In Long Bill Budget)					
						$ x 1000	513						
					Bridge Repair	$ x 1000	290	(In CIP)					
					Safety Improvements	Route Miles			5.0				3.0
					(rebuild road)	$ x 1000			5000				3000
					Safety Improvements (improve alignment)	$ x 1000							1500
					Overlays	Lane Miles				25.4		11.2	39.4
						$ x 1000				635		560	1720
C 13	Craig	Wyoming	Moffat	77.5	Widening	Route Miles	(27.9)					(In CIP)	
						$ x 1000		1295		1000	450		
					Overlays	Lane Miles					1.8		109.6
						$ x 1000					90		2790
US 40	Utah	Maybell	Moffat	130.0	Hill Climb Lanes	$ x 1000			385				770
					.7, .7, .7 miles	Lane Miles		88.0		5.4		2.0	128.0
					Overlays	$ x 1000		2200		135		50	3335
US 40	Maybell	Craig	Moffat	65.0	Drainage Control	$ x 1000	100	(In CIP)					
					Overlays	Lane Miles			24.6	2.4	11.0		92.0
						$ x 1000			705	120	275		2450

Table J Recommended Roadway Improvement Needs

Route	From	To	County	Lane Miles	Project		1980	1981	1982	1983	1984	1985	1986-2000
								Annual Improvement Needs[1]					
US 40	Craig	Moffat-Routt Co. Line	Moffat	16.8	Safety Improvements	Route Miles					6.6		
					(rebuild road)	$ x 1000					6600		
					Overlays	Lane Miles							3.6
						$ x 1000							180
US 50	Whitewater	Grand Junction	Mesa	29.4	Overlays	Lane Miles		10.0		6.4	1.4		21.6
						$ x 1000		350		320	70		1080
C 64	US 40	Moffat-Rio Blanco Co. Line	Moffat	3.4	Overlays	Lane Miles		1.0			2.4		1.0
						$ x 1000		25			120		50
C 64	Moffat-Rio Blanco Co. Line	Rangely	Rio Blanco	38.5	Hill Climb Lanes	$ x 1000		1100		165			
					.9, .8, .3, .3 miles								
					Safety Improvements	Route Miles							4.0
					(rebuild road)	$ x 1000							3010
					Overlays	Lane Miles		30.5	8.0				30.5
						$ x 1000		908	200				1525
C 64	Rangely	Piceance Creek Rd.	Rio Blanco	74.0	Hill Climb Lanes	$ x 1000		842	550				
					.33, .8, .4, .5, .5 miles								
					Safety Improvements	Route Miles							17.0
					(rebuild road)	$ x 1000							17000
					(improve alignment)	$ x 1000							4000
					Overlays	Lane Miles		43.6	30.4				40 0
						$ x 1000		1090	760				2000
C 64	Piceance Creek Rd	Meeker Jct	Rio Blanco	34.2	Safety Improvements	$ x 1000		1750	1750				
					(Improve Alignment)								
					Overlays	Lane Miles		17.0	17.2				34.2
						$ x 1000		425	430				1710
Bus 70	I-70 west of Grand Junction	I-70 east of Grand Junction	Mesa	65.3	Overlays	Lane Miles				31.3	34.0		18.1
						$ x 1000				1233	1700		665
C 82	I-70	Garfield-Eagle Co. Line	Garfield	64.2	Widening	Route Miles	(0.8)						
						$ x 1000		235			400	(In CIP)	
					4 Lane east of	Route Miles						4.1	
					Carbondale	$ x 1000						6150	
					Overlays	Lane Miles				40.8	7.2		56.4
						$ x 1000				1120	180		2420
C 133	C 82	Garfield-Pitkin Co. Line	Garfield	7.8	Safety Improvements	Route Miles				.9			
					(rebuild road)	$ x 1000				540			
					Overlays	Lane Miles							6.0
						$ x 1000							235
C139	I-70 (Loma)	Mesa Garfield Co. Line	Mesa	27.0	Hill Climb Lane	$ x 1000		330					
					.6 mile								
					Safety Improvements	Route Miles				6.0			6.2
					(rebuild road)	$ x 1000				6000			3720
					Overlays	Lane Miles		12.4					2.6
						$ x 1000		310					65

Table J Recommended Roadway Improvement Needs

Route	From	To	County	Lane Miles	Project		Annual Improvement Needs[1] 1980	1981	1982	1983	1984	1985	1986-2000
C 139	Mesa-Garfield Co. Line	Garfield-Rio Blanco Co. Line	Garfield	50.0	Hill Climb Lane .2 mile	$ x 1000			110				
					Safety Improvements (rebuild/renovate road)	Route Miles						4.5	20.5
						$ x 1000						4500	12300
					Overlays	Lane Miles		21.0	4.8		15.2		
						$ x 1000		525	120		380		
C 139	Garfield-Rio Blanco Co. Line	Rangely Jct.	Rio Blanco	66.6	Safety Improvements (rebuild/renovate road)	Route Miles							33.3
						$ x 1000							19980
					Overlays	Lane Miles		16.8	40.0			9.8	
						$ x 1000		420	1000			245	
C146	US 50	Bus 70	Mesa	11.0	Widening	Route Miles	2.0	(In CIP)					
						$ x 1000	1900						
					Overlays	Lane Miles			7.4			3.6	7.4
						$ x 1000			185			90	370
C 318	Utah	Maybell	Moffat	119.4	Overlays	Lane Miles						34.4	72.8
						$ x 1000						860	1820
C 340	Fruita	Grand Junction	Mesa	30.4	4 Lane further west of Grand Junction	Route Miles							6.4
						$ x 1000							9600
					Safety Improvements (rebuild road)	Route Miles					4.4		
						$ x 1000					2640		
					Overlays	Lane Miles					5.4		3.6
						$ x 1000					265		95
I-70	Mack	Garfield-Eagle Co. Line	Mesa, Garfield	385.2 (405.0)	New Roadway	$ x 1000	15210	(In Long Bill Budget)					
						$ x 1000	39510	24600	24800	13700	20000	(In CIP)	
					Overlays	Lane Miles							35.4
						$ x 1000							1760
Piceance Creek Rd	C 64	C 13	Rio Blanco	83.0	Safety Improvements (misc.)	$ x 1000							5000
					Overlays	Lane Miles					13.8	69.2	5.8
						$ x 1000					690	2735	1450

[1] Costs in equivalent 1979 dollars

Source: TDA

development. Highway needs continue after that, but slow down slightly. This is a result of traffic reductions after the initial burst of construction and the shift of products to alternative systems.

Table K summarizes the recommended roadway improvements through 2000 by County. Figures 36 and 37 note the locations of the Recommended Roadway Improvements.

In addition to the highway needs identified in the tables, a Roadway Plan for roads in the Piceance Creek Basin should be adopted. Current projections do not justify construction of these roads now. However, if need for roads in this area develops, they should be built in conformance with the Roadway Plan and to County road standards. (See Figure 32).

Transit System Recommendations

Recommended transit system improvements can be categorized into meeting the needs of one of four service markets — within communities, between communities, elderly and handicapped, and energy-related work trips.

1 Within Communities

The City of Grand Junction and Garfield County will be completing transit development programs in the near future to detail the needs and operating plans for intracity transit services in those communities. In addition, the formulations of local transit planning studies for the communities of Craig, Meeker, Rangely and Rifle should be initiated.

2 Between Communities

Rangely is not currently served by intercity transit services. The privately-owned systems in the region should be requested to investigate the Rangely market. It appears that there is a need to provide an intercity service to Rangely. The growth of Scenario II should encourage the private market to increase levels of service in other areas.

3 Elderly and Handicapped

Vehicle needs for specialized elderly and handicapped services throughout the region are estimated in the near-term at eight vans with an estimated capital cost of $128,000. Transit services should be developed to meet these needs. Annual operating expenses for these new vehicles total approximately $72,000. These costs are detailed in the Colorado Department of Highways report entitled "Specialized Transportation Service Coordination Study."

4 Major Employer Work Trips

A significant portion of the commuting trips of the region's energy workers and the workers for other major employers should be carried in high occupancy vehicles — vanpools, carpools and special buses. An aggressive, coordinated approach to providing these trips in the Axial, Parachute, Roan, and Piceance Creek Basins, should be investigated.

Air System Recommendations

The recommended regional airport system includes Grand Junction and Hayden as large and small air carrier airports, respectively. The other four airports will become commuter service facilities, although

Rifle may develop into a small air carrier airport also with the potential for service by Aspen Airways. The five airports smaller than Grand Junction are not likely to be tied strongly to Grand Junction. The commuter service airports will probably develop some service to/from Denver.

The recommended specific actions with respect to regional airport system development are as follows:

1 Continue development of Grand Junction and Hayden as the large and small air carrier (AC) airports, respectively.

2 Develop Rifle as a commuter service (CS) airport with potential for small air carrier service. Develop the Rifle Airport to Basic Transport (BT) standards.

3 Develop the Rangely, Meeker[1], and Craig airports as commuter service airports in the Basic Transport design category.

4 Implement as many of the airport improvements shown on Table L as possible. These improvements, which total $45 million in cost, are nearly all from the Phase I (0 to 5 years) development schedules from the individual airport master plans.[2]

5 Update the individual airport master plan reports as necessary to respond to continued energy development.

Table L summarizes the projected capital needs for the runway, taxiway and terminal improvements described in Chapter 4.

Table L Recommended Airport Improvements

Airport	Improvement Elements Phase I (0-5 Years)	Estimated Aggregate Cost, 1979 Dollars
Grand Junction	Expand new air carrier apron; construct new terminal building, access roads, and auto parking; overlay runway 11/29, taxiway, apron; expand general aviation apron; acquire land.	$16.3 million
Hayden	Overlay expand apron; widen/strengthen runway 10/28, connecting taxiways; acquire land; extend runway 10/28; construct parallel taxiway.	$ 9.4
Rifle	Overlay runway 7/25; expand apron; construct connecting taxiway; install utilities, fuel facilities; relocate buildings; construct new runway 8/26, parallel taxiway; install navaids; acquire land; construct CFR building; acquire vehicle.	$ 6.4
Rangely	Acquire land; relocate road; extend runway 6/24 and parallel taxiway; install non-directional beacon.	$ 1.5
Meeker	Acquire land; extend/widen runway 3/21; expand apron, construct parallel taxiway.	$ 3.3
Craig	Overlay runway, taxiway, apron; acquire land; extend runway 7/25; construct parallel taxiway.	$ 8.4
Total		$45.3 million

Source. Isbill Associates, Inc.; TDA, Inc.

Rail System Recommendations

The specifics of any rail system improvements are within the province of the railroads and their customers. However, because of the effect of rail service on highway needs and the potential to reduce highway-related community impacts, we recommend that rail

1 Meeker sponsor may relocate airport

2 A pre-application for $20 million in FAA funds was submitted by the Walker Field (Grand Junction) Public Airport Authority to the FAA in December 1979. The pre-application improvement items, if merged with the items shown on Table L, total $29.7 million. The pre-application does not include the new terminal construction but does add several other items.

Table K **Roadway Improvement Needs by County.**
(Dollars in thousands.)

County	Projects		Costs[4] 1980	1981	1982	1983	1984	1985	Sub Total 1980-1985	1986-2000	Total 1980-2000
Mesa[1] 214 9 lane miles	Currently Programmed	Widen	1900						1900		1900
		Overlay									
		Misc.									
		Subtotal	1900						1900		1900
	Additional Recommendation	Safety Improvements				6000	2640		8640	3720	12360
		Widen								19050	19050
		Hill Climb Lane		330					330		330
		Overlay		830	705	2803	2035		6373	2560	8933
		Subtotal		1160	705	8803	4675		15343	25330	40673
	Total		1900	1160	705	8803	4675	0	17243	25330	42573
Garfield[1] 205 0 lane miles	Currently Programmed	Widen		235			400		635		635
		Overlay									
		Misc.									
		Subtotal		235			400		635		635
	Additional Recommendation	Safety Improvements				540		4500	5040	27900	32940
		Widen						6150	6150		6150
		Hill Climb Lane		220	110				330		330
		Overlay		630	925	1480	1165	240	4440	4365	8805
		Subtotal		850	1035	2020	1165	10890	15960	32265	48225
	Total		0	1085	1035	2020	1565	10890	16595	32265	48860
Rio Blanco 380 9 lane miles	Currently Programmed	Widen									
		Overlay	522						522		522
		Misc.									
		Subtotal	522						522		522
	Additional Recommendation	Safety Improvements		3750	1750				5500	64065	69565
		Widen									
		Hill Climb Lane		1942	550	165			2657		2657
		Overlay		3398	3020	545	690	3550	11203	9140	20343
		Subtotal		9090	5320	710	690	3550	19360	73205	92565
	Total		522	9090	5320	710	690	3550	19882	73205	93087

Table K **Roadway Improvement Needs by County.**
(Dollars in thousands.)

County	Projects		Costs[4] 1980	1981	1982	1983	1984	1985	Sub Total 1980-1985	1986-2000	Total 1980-2000
Moffat 472.8 lane miles	Currently Programmed	Widen		1295		1000	450		2745		2745
		Overlay	513						513		513
		Misc	390						390		390
		Subtotal	903	1295		1000	450		3648		3648
	Additional Recommendation	Safety Improvements			5000		6600		11600	4500	16100
		Widen									
		Hill Climb Lane			385				385	770	1155
		Overlay		2225	705	890	485	1470	5775	10140	15915
		Subtotal		2225	6090	890	7085	1470	17760	15410	33170
	Total		903	3520	6090	1890	7535	1470	21408	15410	36818
Study Area Total[1] 1273.6 lane miles	Currently Programmed	Widen	1900	1530		1000	850		5280		5280
		Overlay	1035						1035		1035
		Misc	390						390		390
		Subtotal	3325	1530		1000	850		6705		6705
	Additional Recommendation	Safety Improvements		3750	6750	6540	9240	4500	30780	100185	130965
		Widen						6150	6150	19050	25200
		Hill Climb Lane		2492	1045	165			3702	770	4472
		Overlay		7083	5355	5718	4375	5260	27791	26205	53996
		Subtotal		13325	13150	12423	13615	15910	68423	146210	214633
	Total		3325	14855	13150	13423	14465	15910	75128	146210	221338
I-70 385.2 lane miles (485.0 lane miles)2	Currently Programmed[3]		54720	24600	24800	13700	20000		137820		

[1] Does not include I-70

[2] Upon completion of all sections in study area.

[3] Additional needs not projected herein

[4] Costs in equivalent 1979 dollars.

Source: TDA

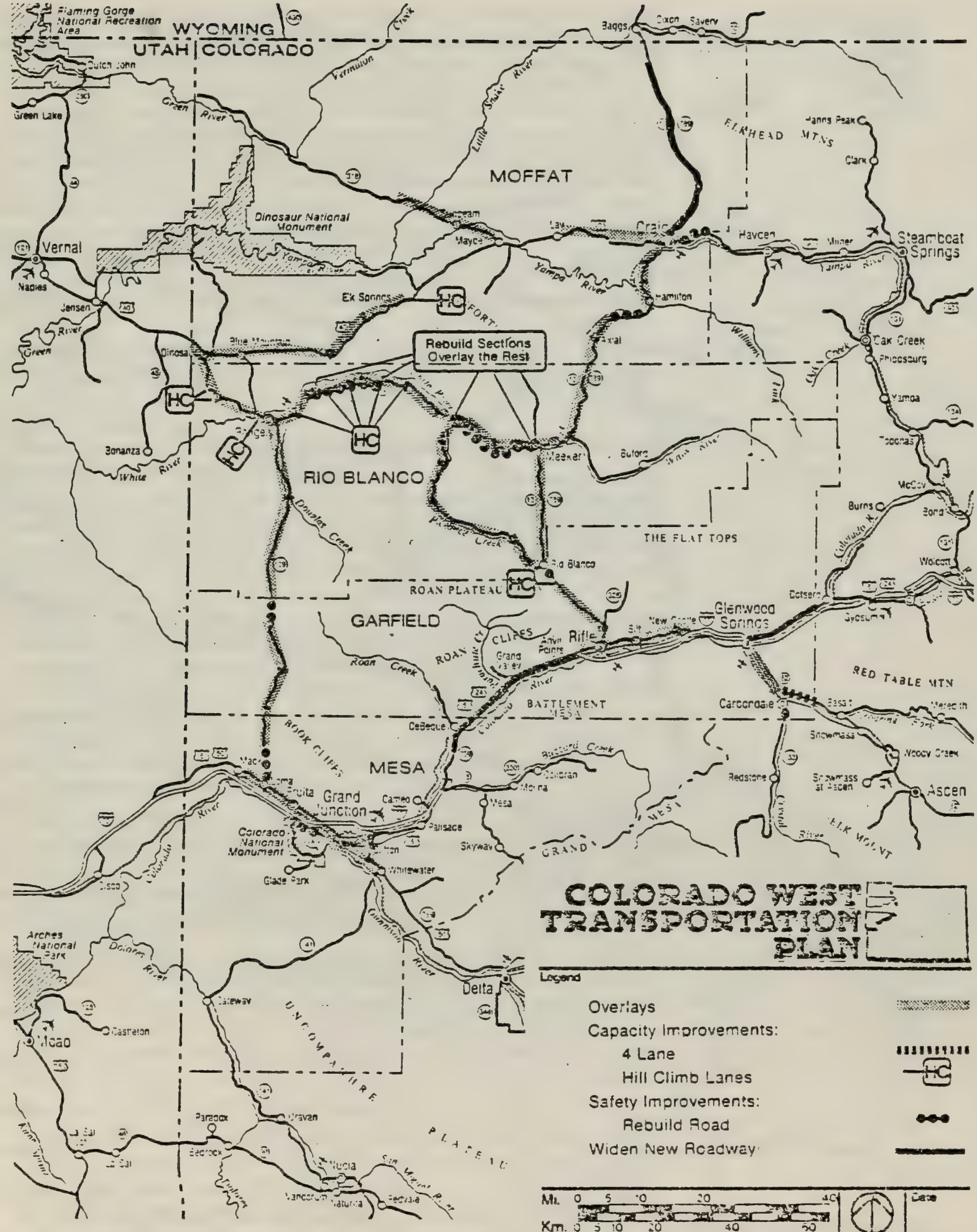


Figure 36 Highway Needs 1980-1985

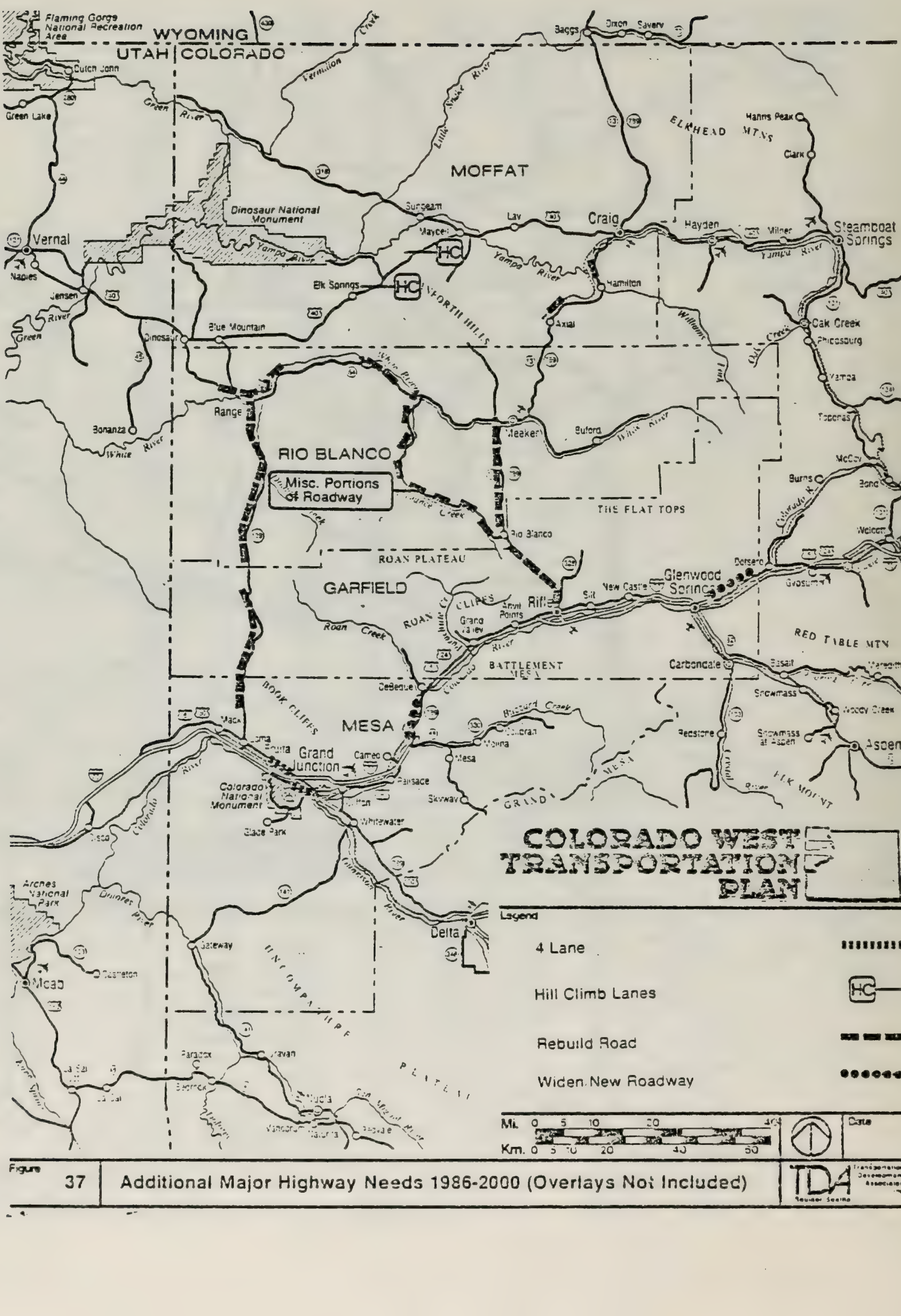


Figure 37 Additional Major Highway Needs 1986-2000 (Overlays Not Included)

service be provided to Superior by the time that it reaches estimated 1990 production levels. This improvement is summarized in Table M. It would appear that the most likely way of achieving this is extending the D&RGW Craig line from its current terminus at COLOWYO, potentially in stages depending on the actual level of development of coal mines north of Meeker. However, other rail connections to these energy sites could have similar beneficial impact on the highway needs. For example, a Union Pacific extension south from Wyoming and into the area could potentially serve the needs. Permits for new or expanded energy development activities should be keyed to the availability of either rail or pipeline systems.

Table M Recommended Rail Improvements

Recommended Improvement	Year Ready	Trigger	Respon-sibility	Capital Cost 1979 $
Rail to Superior (from Axial)	1990	Projected 1990 shale oil and by-product	Private	$60 - $100 M

Source: TDA.

Pipeline System Recommendations

It is important from the standpoint of the regional highway system and community impact that production-level oil shale facilities be served by pipelines. Construction of these pipelines will be a private sector responsibility. The public sector is involved through the permit process and the provision of rights-of-way across public land. Probably the economics of oil transportation will require shipment by pipeline in any event, but even interim periods of hauling by truck would seriously impact the highway system. Therefore, we recommend that no plant be permitted to produce more than 15,000 barrels a day without shipment by pipeline. Also, to the extent physically and economically practical, common carrier pipelines and joint use of utility corridors should be encouraged as a means of minimizing environmental disruption.

Electric Transmission

No further mine-mouth generation was projected in growth Scenario II. Any additional electric transmission lines to be built should be located in joint utility corridors, to the extent possible.

Recommendations by Responsible Agency

Even though the sponsor of this study is the Colorado West Area Council of Governments, the plan involves the actions of several different "clients." Because responsibility for various parts of the plan rest with the towns and cities, the counties, the State, the Council of Governments, and the energy projects themselves, this section will summarize recommendations by "client."

Regional (Colorado West Area Council of Governments)

1 Assist Garfield and Rio Blanco Counties in adopting a Piceance Creek Roadway Plan and in establishing minimum standards for any road improvements in that area.

2 Consider the creation of a regional service authority for transit, as enabled under the Regional Service Authority Act of 1972 (C.R.S., 1973. 32-7). The transit needs of the Colorado West region cross county boundaries. Therefore, there is a need for a regional

perspective. A regional service authority could serve as a "broker" for the many transit service markets in the Colorado West Region. This agency would coordinate both private and public sector transportation as well as operate some services not provided by other entities or companies. As a first step toward this end, the CWACOG should apply to the Urban Mass Transportation Administration (UMTA) for Section 9 funds to complete a region-wide transit development program (TDP). This TDP could detail the regional transit needs of the intercity, elderly and handicapped, and worker trip markets. Specific consideration should be given to the needs of the Grand Junction, Fruita, Palisade area. The intracity needs of Craig, Meeker, Rangely, and Rifle should also be investigated at that time.

3 . Establish a process for continuing update of the Regional Transportation Plan. Scenario II represents today's "best guess" of energy development, but almost certainly there will be changes. Because rail, pipeline and electric transmission lines are generally controlled by the private sector, the update process need only address the critical issues. For example, a change in energy development could change the timing and need for improvements. Particular attention should be paid to:

- The possible lag time between beginning of production and availability of the long-term product transportation mode — rail or pipeline.
- The timing of need compared to that of available revenues.
- Any unusual requirements of the construction period. For example, use of a short section of highway to connect a borro.. pit or gravel plant to the energy site could have serious short-term effects on traffic and long-term effects on pavement life.

4 Consider the need for improved legislation allowing the oil shale projects to prepay some taxes. This would make funds available earlier, rather than after needs develop.

5 Develop and adopt a financial strategy in conjunction with the counties and cities. Principles should be established as to which source pays for which needs and estimating likely levels of funding by source.

6 Conduct a highway traffic safety study. Through the course of this regional transportation analysis it was clear that a region wide safety study should be conducted to identify specific safety improvements that are currently needed, and will be needed even more as energy development occurs.

Counties

1 Through the permitting process, require simultaneous completion of energy projects and their related rail and pipeline links. This will minimize product-haul impact through communities and on the regional highway system.

2 Garfield and Rio Blanco Counties should adopt the Piceance Creek Basin Master Roadway Plan for roads and *should require* t. any roads built in that area, whether by the energy projects, Bureau of Land Management or other agency, follow this master plan and meet adequate county road standards. This latter point is important

to assure that the counties will not be faced with unreasonable maintenance costs. These standards should include width, grade, curvature, drainage and surface requirements. Following this plan and road standards will help to minimize maintenance costs and environmental costs.

3 Support improvements at the region's airports to bring them up to the recommended system plan:

- Grand Junction (Walker Field): large air carrier airport
- Hayden (Yampa Valley Airport): small air carrier airport
- Rifle (Garfield County Airport): commuter service/small air carrier (Basic Transport design standards)
- Craig: commuter service (Basic Transport design standards)
- Meeker: commuter service (Basic Transport design standards)
- Rangely: commuter service (Basic Transport design standards)

4 Develop and adopt with CWACOG and the cities and towns a financial strategy establishing principles as to which source pays for which needs, and estimating likely levels of funding by source.

5 Cooperate with the cities and CWACOG on developing plans and providing services to meet the region's transit needs.

6 As a key means of holding down vehicle miles travelled, air pollution, and transportation-related government costs, formulate and implement land use plans designed to encourage growth to locate in urban areas rather than scattered or sprawled throughout the counties.

7 Analyze existing and projected railroad grade crossings in the urbanizing areas and develop an action plan to construct needed grade separations and other safety improvements.

Cities and Towns

This study dealt with regional needs and did not address specific travel problems within the communities. However, it is clear that such problems will be a major impact of energy development. In consideration of this, we recommend that the cities and towns take at least the following recommended actions:

1 Begin study of transit needs (see previous Transit Recommendations); the extent of actual need depends very much on specific local conditions and desires. This consideration should be beyond city limits and include the county or the region.

2 The critically important relationship between community growth patterns and traffic volumes needs to be understood and emphasized. Growth plans aimed at encouraging concentrated land use patterns should be formulated for the towns and cities in the region. This will minimize sprawl and its extravagant dependence on the automobile.

3 If the region is to follow through on the goal to concentrate growth in existing communities, the cities and towns should develop institutional capacity for growth, including the capacity to deal with their street and highway problems. This will require establishment of effective development project review procedures, street standards, overall street plans, and financing of street and signal improvements.

4 Develop and adopt a financial strategy in conjunction with the counties and CWACOG, establishing principles as to which source

pays for which needs, and estimating likely levels of funding by source.

Colorado Department of Highways

1 No new regional highways are required in the State highway road system in the region. While the roadways will require improvement over the next twenty years, the present network provides a reasonable pattern of connection among the major activity areas of the four-county region. Depending upon local traffic patterns, truck traffic and other conditions, construction of bypass highways around cities and towns may be required.

Consideration should be given to adding the Piceance Creek Road to the State highway system. The current function of the roadway with respect to accommodating energy products and employees is clear. Future energy activities will increase the use of this road for energy development purposes. Due to the regional nature of the traffic on this road, the State Highway Department should collect the data required to consider adding Piceance Creek Road to the State highway system.

2 Complete the improvements scheduled on Table J or as revised in the continuing update of the regional plan.

3 Cooperate with the CWAGOG on continuing update of the regional transportation plan.

Energy Projects

1 Maximize shipments of products by rail and pipeline at all stage of development.

2 Contribute initial capital funds and/or prepay some taxes as a means of minimizing lead time problems.

Federal Agencies

1 Create a fund for "Energy" roads, serving energy sites, recognizing that their need is a direct consequence of national energy policy.

2 Expedite approvals, permits and leases for pipelines and rail extensions.

Financial Considerations

Previous sections of this Recommendations chapter have summarized costs for publicly-owned transportation improvements. Such costs will be at least partially offset by the direct and indirect revenues received from energy resource development and other sources in the region. This section describes potential sources, and overall financing strategy and specific financing considerations for highways, transit and airports.

Potential Revenue Sources

Revenues can be categorized as those which are typically used to fund local and state government activities throughout Colorado and those which are unique to areas experiencing energy or other mineral development.

The following revenue sources are typically found in the first category:

- State income taxes
- State sales and use taxes

- State motor fuel tax
- State vehicle tax
- State gross ton mile tax
- Local property tax
- Local sales tax

The revenues from these usual sources will help fund some of the government service and facility needs in northwest Colorado. However, many studies have shown that these revenue sources are not adequate to fund the needed services and facilities in a rapidly growing but still sparsely populated region. In addition, several of these revenue sources have problems which reduce their effectiveness. For example:

- Property taxes will increase, both directly because of the value of the energy mines and plants and indirectly because of the value of the property that will be developed to support the increased population. However, these taxes have a one to two year lag between the creation of the assessed value and the payment of the tax.
- In addition, the revenues gained from property taxes can be utilized only within the boundaries of the jurisdiction which levies the tax. In northwest Colorado this means that those local government jurisdictions which have energy resources, mines, and/or plants within their boundaries can levy a property tax on them. However, there are many local jurisdictions which will be impacted by the development of the resources, but, because they do not have such mines and/or plants within their jurisdiction, will be unable to receive property tax revenues from them.
- Private residential and commercial developers will fund some of the urban street needs related to growth. However, these funds will not pay for the ongoing street maintenance costs.
- Because of inflation, future growth rates of revenues are very uncertain. For example, the real value of highway user taxes has been declining rapidly, even though the number of dollars has been rising slowly.

Revenue sources utilized throughout Colorado to fund local and state government activities will help fund the needed services and facilities in northwest Colorado but will be unable to fund all of them in a timely way. This is so because of such problems as time lag, taxing entity boundary limitations, inadequate revenues vs. increasingly costly government services and facilities, minimal initial local tax bases, and competition for limited state revenues by more populated regions.

Because usual revenue sources were found to be inadequate, an analysis was made of the revenues unique to those areas experiencing energy or other mineral development activities. These revenue sources include:

- State Severance Tax
- Federal Mineral Leasing revenues
- Oil Shale Trust Fund

1 State Severance Tax

The Colorado Mineral Severance Tax was established through the passage of House Bill 1076 (1977). Monies from this tax go to one of two funds — the State Severance Tax Trust Fund or the Local

Government Severance Tax Fund. The State Severance Tax Trust Fund "is to be perpetual and held in trust as a replacement for depleted natural resources. The income from the investment of such trust funds shall be deposited in the state's general fund."[1]

The funds in the Local Government Severance Tax Fund are distributed by the Executive Director of the Department of Local Affairs upon the advice of the Energy Impact Assistance Advisory Committee. These funds are to be distributed on the basis of 85% to "political subdivisions socially or economically impacted by the development, processing, or energy conversion of minerals and mineral fuels subject to taxation under this article and used for the planning, construction, and maintenance of public facilities and for the provision of public services"[2] and 15% to local government jurisdictions in which mineral resource workers reside.

The State severance tax on oil and gas is a relatively low yield tax. It is a tax of between 2% and 5% of the gross income of the operation minus 87½% of the property tax paid by the operation. The tax on coal is 60 cents per ton for surface mined coal and 30 cents per ton for underground mined coal. No tax is levied on the first 8,000 tons of coal produced in each quarter of the taxable year. During the July 1, 1978 — June 30, 1979 period approximately $3,000,000 was paid to the State from these sources.

The Act also imposes a severance tax on oil shale. This tax is to be levied on the "gross proceeds" from each commercial oil shale facility at a rate of 4% of such gross proceeds. "Gross proceeds" is defined as the value of the oil shale at the point of severance minus most development and operating costs. This tax is to be levied only after a commercial oil shale facility reaches a daily production average of 50 percent of its design capacity. Based on these criteria it is estimated that it will be at least 12 years after the start of construction of an oil shale plant before any severance tax is received from the operation of the plant. After that it is estimated that $3,000,000 to $5,000,000 in severance taxes would be derived annually from a 50,000 barrel a day oil shale plant.

After July 1, 1981, 50% of the severance tax monies received from coal and oil shale will be allocated to the State General Fund and 50% to the Local Government Severance Tax Fund. Based upon the production projections included in this report, it is estimated that at the existing tax rates this tax would yield approximately $14,000,000 annually by 1990. This would be distributed as follows:

50% State General Fund		— $7,000,000
50% Local Severance Tax Fund		— $7,000,000
• 15% — to local jurisdictions where the energy workers reside	— $1,000,000	
• 85% — to political subdivisions impacted by energy development activities	— $6,000,000	

2 Federal Mineral Leasing Act

The Federal Coal Leasing Amendments Act as amended requires 50% of the money collected as bonuses, rentals or royalties from Federal mineral leases be returned to the State. The State of

1 House Bill 1076 (1977) - Section 39-29-109 (1)

2 House Bill 1076 (1977) - Section 39-29-110 (1) (b)

Colorado distributes this money as follows:

- 25% — State Public School Fund
- 50% — to the County in which funds originate with a maximum of \$20,000 to any county in one year. The balance then goes to the State Public School Fund
- 10% — Water Conservation Board
- 15% — Local Government Mineral Impact Fund administered by the Department of Local Affairs

Approximately \$6,200,000 was returned to Colorado for activities throughout the State under this program between July 1, 1978 and June 30, 1979.

The coal royalties to be paid to the Federal Government can be no less than 12.5% of the selling price at the mine month. Most leases are selected on a bid basis and obviously they only apply to mines on Federal lands. These factors make it impossible to predict reliably the revenues that would be made available as a result of the Federal coal leasing program in Northwest Colorado. However, in order to get an idea of the potential size of these funds, a theoretical analysis based upon the 1990 projections for coal production in the region was made. The following are the key assumptions and results of this analysis.

Assumed Royalty Level	— 12.5% of selling price
Assumed Selling Price	— \$20/ton
Assumed Annual Tonnage of Coal Mined From Public Lands (2/3 of tonnage mined in region)	— 12,500,000 tons
Annual Royalty Income	— \$31,000,000
State Share	— \$15,500,000
Portion of State Share Contributed to the Local Government Mineral Impact Fund	— \$2,500,000

3 Oil Shale Trust Fund

This Trust Fund was established by House Bill 1046 (1974). It places oil shale payments received by the State from the Federal Mining Lands Leasing Act of 1920 into a special fund appropriated by the General Assembly to state agencies, school districts, and political subdivisions for planning and the provision of needed public services and facilities. In 1975 Senate Bill 54 was passed to allow the interest from the investment of Oil Shale Trust monies to be used for impact assistance.

The Oil Shale Trust Fund was initially funded through the receipt of three lease payments for the C-a and C-b sites totalling approximately \$73,800,000. A portion of these funds plus the accrued interest has been utilized to fund state and local plans and facilities in the oil shale impacted area of Colorado. As a result, in early 1979 the Fund had a balance of approximately \$59,000,000 and interest accruing at the rate of about \$5,000,000 a year. During the past several years the appropriations from the Fund have been greater than the accrued interest. Therefore the appropriations have included both fund principal and interest.

As additional oil shale activity occurs in the region on public lands, additional monies could be distributed to this trust fund.

However the amount of these funds is impossible to predict. There are many variations and uncertainties in how such leasing would be undertaken and how the State would receive lease and royalty payments.

All three of these sources offer the potential to solve some of the government service and facility funding problems in the region. It should also be noted that none of these are earmarked for transportation facilities and services. As a result, transportation now competes and will continue to have to compete with the many other demands for these funds. It is apparent that, at least for now, the cost of providing needed services and facilities is rising faster than many of the revenue sources. However, several of the taxes such as the State Severance Tax on oil from oil shale and the Federal royalties requirements on coal are keyed to energy resource prices. This may help to offset the inflation of costs.

Because of this, this section takes the approach of:

- Recommending strategies for county and regional consideration which, when adopted, may provide a basis for ongoing decisions on assignments of sources of revenue to prioritized transportation projects.
- Comparing, at least for highways and airports, total costs with a rough estimate of earmarked funds that will be specifically available for those costs.
- Identifying potential sources of revenues for meeting the differences between expected costs and earmarked revenues.

Financing Strategy

In the face of this kind of energy development and growth, the towns, cities and counties are confronted with costs in at least three categories:

- Those that are associated directly with the energy development; for example, the construction and maintenance of a road serving an energy site.
- Those costs related indirectly to energy development. The employment needs of energy development will result in a corresponding increase in population and thereby an increase in the need for facilities and services — schools, local streets, water supply and waste disposal, police and fire protection, and a host of others.
- The costs of normal growth and improvement that would have been there without the energy development.

Existing Local and State tax structures, at least theoretically, address the needs of the last category of costs. The first two categories, however, are not met in a timely way under the existing tax structure.

A recommended approach to assignments of financial responsibility for these unmet costs is:

1 The transportation needs directly related to energy development should be supported by the energy projects themselves. Whether that payment comes from the private energy developer or the Federal Government depends in large measure at the national level on the degree to which our national synthetic fuels program will move

ahead in the private sector versus how much it will be a Federal energy program.

2 The schedule of development is expected to be more nearly related to national needs than the local area's ability to absorb that growth. The costs of providing services in rapid growth communities are higher than those with a more orderly pace and the costs occur much more quickly than do the local and state revenues that will be derived from that growth. Therefore, the energy projects, *whether by private or Federal money,* should help support both the extra costs of rapid growth and the cash flow problems of income lagging behind expense.

The following sections apply these principles to the needs of highways, transit and airports.

Highway

Figure 38 presents a summary comparison of expected Capital needs through the year 2000. The first bar represents our initial estimates of the very minimum requirements to accomodate Scenario II Energy Development. That is, it includes structural overlays and some minor capacity improvements. It does not address the safety improvements currently needed, or major roadway reconstruction and cross section widening.

The second bar represents the amount of needs required to accomodate the Scenario II Energy Development as described earlier in this chapter and as represented by the projects in Table J. The needs shown do not include $140 million for I-70 because of its non-typical nature.

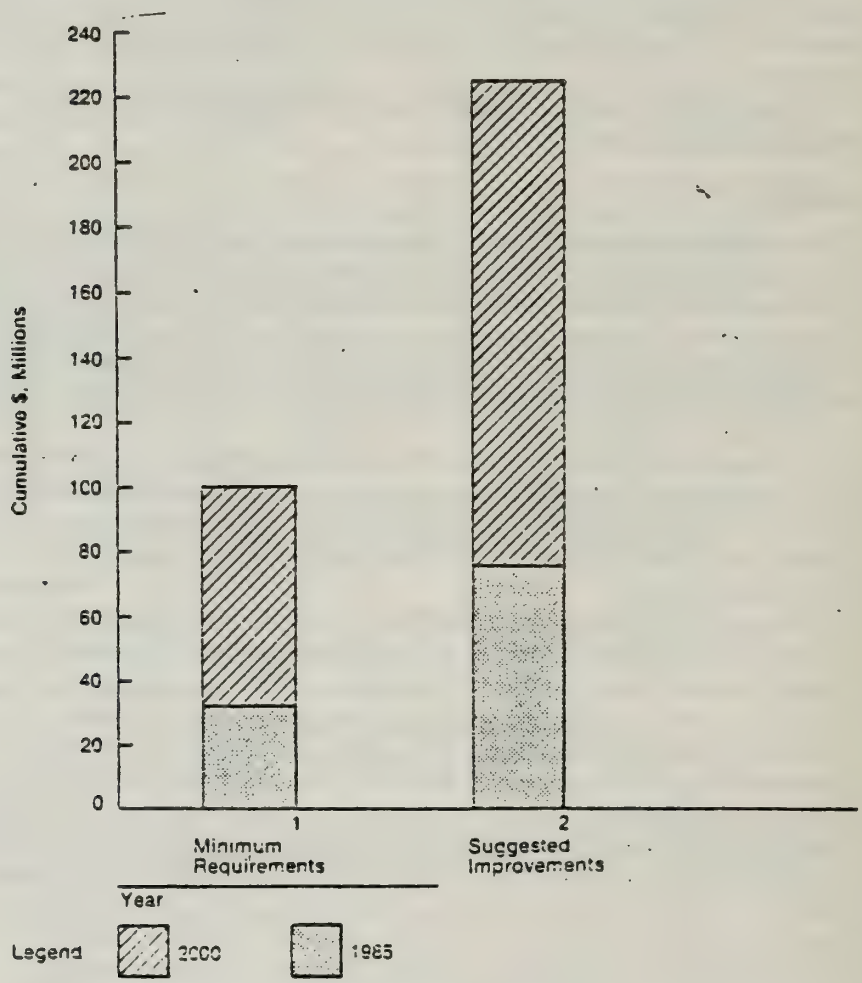
Figure 39 presents a comparison of the recommended highway needs with projected highway revenues for the four County region, under historic funding levels. These projections were based on recent experience. Current Highway Department expenditures on non-interstate state highways in the area are in the $2-3 million annual range. Recent history offers no prospects of a gradual increase in available funds. Total Highway Department expenditures have been growing over the last three years at about 4½ percent per year. However, increases in the cost of highway construction have led to a 12 percent *annual decline* in the value of construction over the last three years. The difficulty in projecting the difference between inflation in highway construction and whatever increases the State makes in highway funding make long-term projections (anything beyond a year) precarious. The projection of Figure 39 is based on an estimated current funding level of about $2.6 million a year in the four counties, projected to continue but decline in value from 2.7 to 12.6 percent a year because of inflation. Federal aid up to the limit of the State's ability to match it was assumed in this revenue projection.

As noted in Figure 39, the gap between needs and revenues is significant. It would amount to about $60 million by 1985 and approximately $180 million by the year 2000 (considering the high revenue estimate). It is the result of not only existing needs, but of those existing needs exacerbated by energy development and of new requirements due to energy development.

We recommend that this gap be filled by the energy development programs utilizing a combination of both Federal and private funds.

The specific funding arrangement would most appropriately be worked out at the Federal level with private energy developers. The source of the funding — windfall profits tax, leasing monies — should be determined at this level.

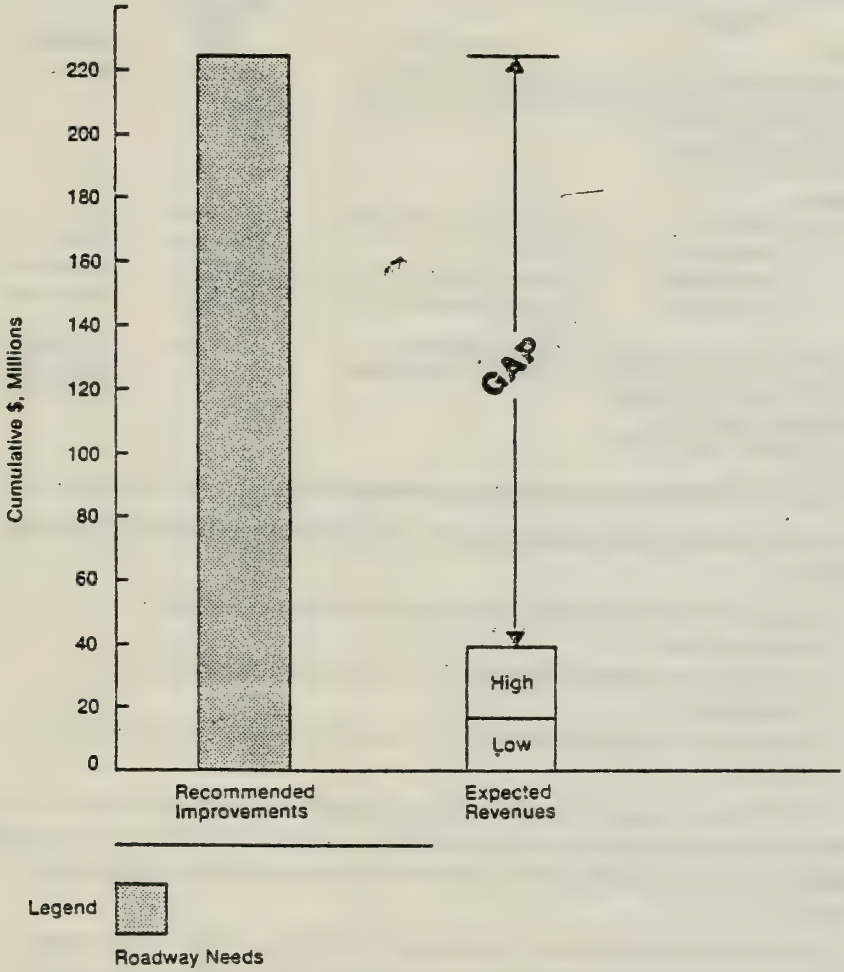
Figure 38
Roadway Needs to Meet Scenario II Energy Development



1 Includes bringing pavement structure to acceptable levels and minor capacity improvements.
2 Includes projects detailed in Table J.

Source: TDA Inc.

Figure 39
Highway Needs vs Projected Revenues Through Year 2000



Source: TDA Inc.

Transit

Potential sources of transit funds are identified in Table N. In general, funding would have to come from local and Federal sources. There are no significant sources of State funding for general public transit, but some State agencies do have money for elderly and handicapped services. Local sources of funds would come from user fares, sales and property taxes, and employer subsidization. Federal sources of funds include the Urban Mass Transportation Administration (UMTA) and the Department of Health, Education, and Welfare (HEW) for general public transit and specialized elderly and handicapped services, respectively.

Airports

There are a number of sources of funds which can be considered for developing the recommended airport improvements.

1 FAA Airport and Airway Development Act of 1970, as amended in 1976. FAA participates for 80 percent of the cost of most eligible

Table N Finance Options Regarding Transit

Source	Applicability	Estimated Annual Yield	Likelihood
State			
1. There exist approximately four programs sponsored by various State agencies for specialized elderly and handicapped services.	Capital and Operating — Elderly and Handicapped	Unknown	Good
Federal			
1. UMTA - Section 3	Capital - General Services	Unknown	Fair
Section 9	Planning	Unknown	Good
Section 16(b)2	Capital - Elderly & Handicapped	----	Committed
Section 18	Capital & Operating - Rural Areas	$62,000	Committed
2. There exist approximately 100 programs administered by various Federal agencies for specialized elderly and handicapped transportation services.	Capital & Operating - Elderly and Handicapped	Unknown	Very good, some already being used

improvements. The available funds are distributed approximately as follows:

- One-third to air-carrier airports based on passenger enplanements
- One-third to general aviation airports through statewide allocations
- One-third discretionary which more often goes to air carrier airports

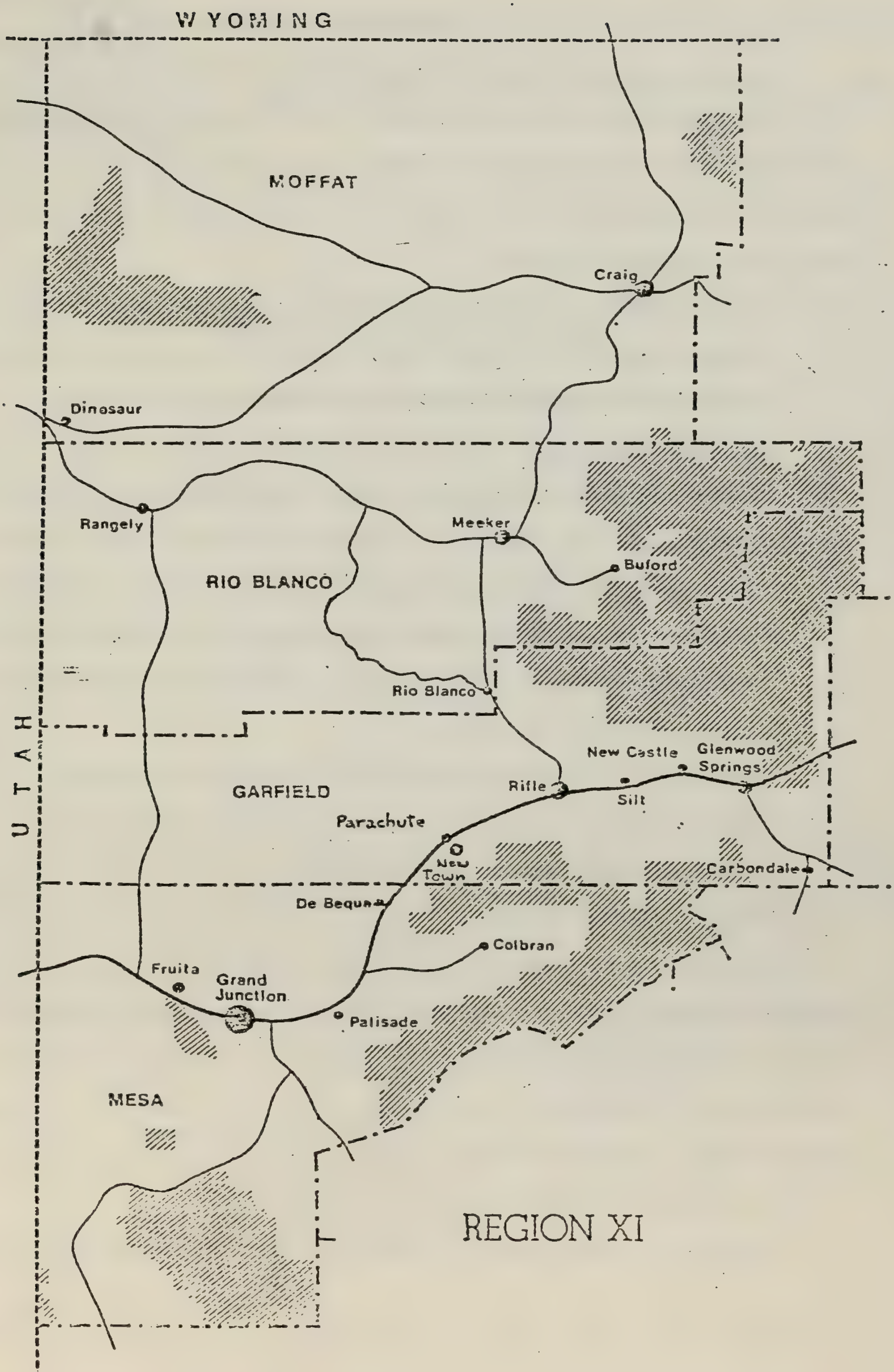
2 Oil Shale Impact Trust Fund is supposed to aid communities that are directly impacted by oil shale development. These funds could be used for airport development, but competition for these monies is great.

3 The Federal Economic Development Agency (EDA) aids small towns in community development projects. Airports can be eligible for EDA monies.

4 The Public Works and Development Act of 1965 makes Federal funds available to economically depressed communities through the Four Corners Regional Commission. The Commission has aided in airport development projects, and currently has an interest in air commuter service within the Four Corners Region.

5 Local business and industry that benefit from airport development are a potential source of funds.

The FAA's Airport and Airway Development Act provides the greatest amount of funds for airport development. However, the airport development needs of the nation greatly outweigh the funding ability of this Act. The current legislation expires on October 1, 1980. Several programs have been proposed to fund airport development after that date, but it is too early to determine which of the proposals is likely to survive. However, the general expectation is that a new program would at least continue the current funding


WYOMING
MOFFAT
Craig
Dinosaur
Rangely
Meeker
Buford
RIO BLANCO
Rio Blanco
UTAH
GARFIELD
Parachute
New Castle
Glenwood Springs
Rifle
Silt
New Town
Carbondale
De Beque
Colbran
Fruita
Grand Junction
Palisade
MESA

REGION XI

METHODOLOGY

REGION XI POPULATION PROJECTIONS

The population projections contained within this report were conducted by the Colorado West Area Council of Governments in July, 1980. The population projections were derived from a computer model which incorporated the following factors into its calculations:

- 1980 population estimates which are based upon preliminary U.S. Census housing counts with assumed vacancy rates of 3 to 4 percent and associated family multipliers for incorporated communities and counties.
- baseline (scenario I) population projections which reflect a revision of earlier baseline projections which were based upon 1960-1977 U.S. Census data. The revised baseline utilizes actual vital rates (births and deaths) and historical migration rates to obtain the baseline natural growth (without energy development) for the 1980-2000 period.
- energy company base worker employment projections with accompanying family multiplier of (2.71).
- base worker distributions assigned by community and county.
- non-base support worker multipliers (which range from .1 to 2.0) with accompanying family multipliers (3.04).
- cohert survival factors. *

The population data within this report includes: 1977 special census, 1980 population estimates, preliminary U.S. Census housing counts, and population projections for each impacted county, community and balance of county (B.O.C.) within Region XI for the years 1980-1985, 1990, and the year 2000. There are three seperate population growth scenarios.

The population projection scenarios are as follows:

Scenario I - Normal population growth without energy development or other

* Seperate projections are available for elderly and school age children.

APPENDIX 13B

COLORADO WEST AREA

council of governments

RIO BLANCO MOFFAT MESA GARFIELD

REGION XI POPULATION PROJECTIONS

MUNICIPAL AND COUNTY POPULATION

PROJECTIONS: 1980 - 2000

AUGUST 1980

Robert G. Demos, Executive Director

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Robert Robinson, Demographic Consultant

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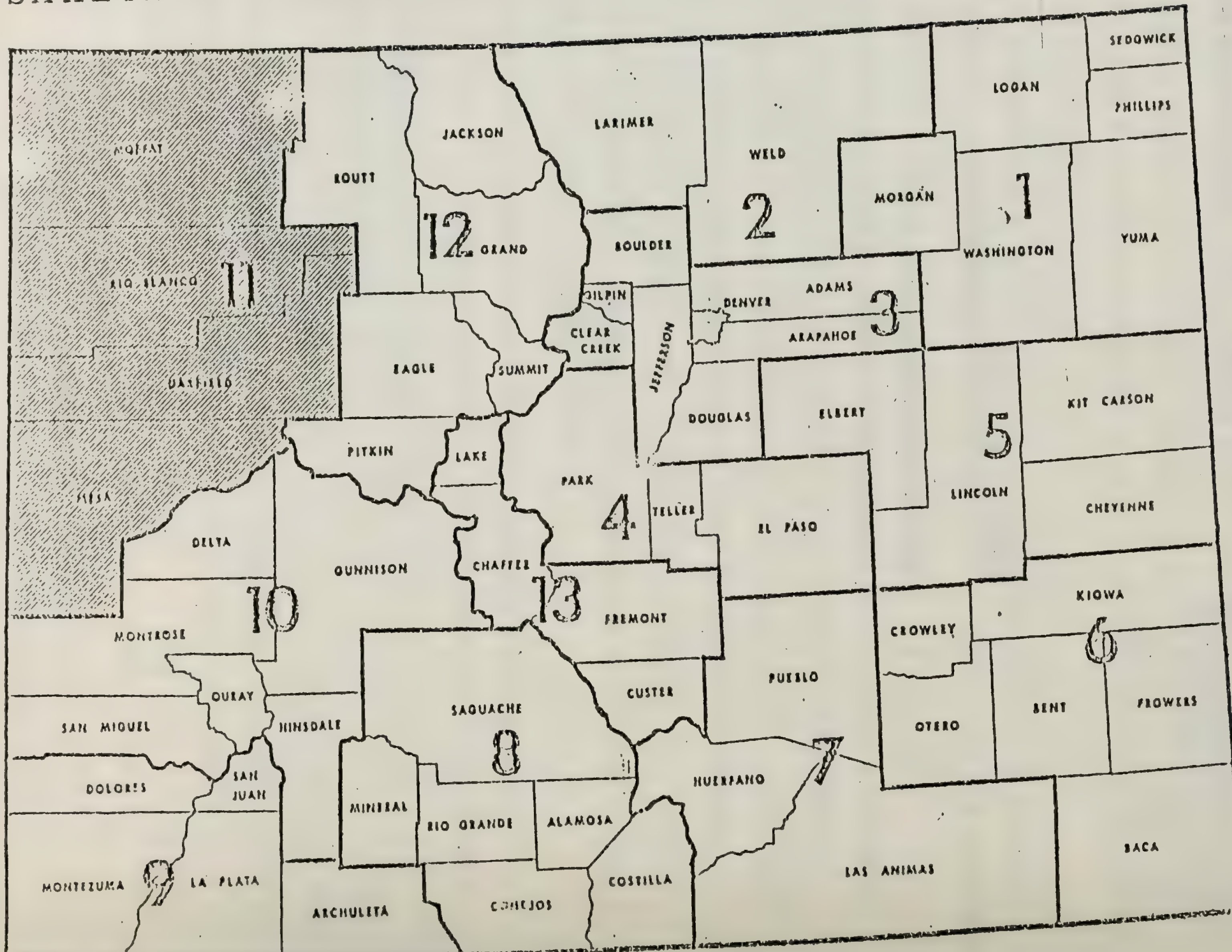
STATE PLANNING REGIONS



major short term growth factors.

Scenario II - Energy development projected with coal and oil shale development as is currently planned (see below for list of companies).

Scenario III - Energy development projected with energy development at a high level of production of shale oil, 450,000 barrels a day by 1990 and 640,000 barrels a day by the year 2000; and a coal production level of 26 million tons per year by 1985 and 34 million tons per year by the year 2000.

Scenario III is based upon the President's proposed program for synthetic fuel development with production levels for shale oil as noted above. The Scenario III population figures have been accepted by the U.S. Environmental Protection Agency and provide the basis for the revised and officially approved 208 EPA/BEA population projections for the State of Colorado.

It should be noted, however, that Scenario II has been selected by the Colorado West Area Council of Governments Board as the Region's officially endorsed population projections. Scenarios I and III are provided in order to provide a reference point and a range of population growth. Scenario II is selected because it reflects the stated plans of the various energy companies which, either are actively involved in development operations, or are actively pursuing development plans in Region XI.

Both Scenarios II and III of this report reflect the total population actually needed (both basic and non-basic support) to adequately accommodate anticipated energy development and secondary services. Therefore, Scenarios II and III in essence reflect what the population should be for the area to properly function and not necessarily what might actually occur. Actual population levels could vary greatly depending upon a multitude of variables, the main variable being the energy companies actual work force scheduling, and in particular, the level of effort, program development, and commitment of

resources to adequately support the level of growth required to meet energy company production schedules. Unless major accommodation efforts are continued and expanded, serious problems can be anticipated from 1981 through 1984 for the Region as a whole and particularly in the Rifle/Meeker growth impacted area.

The energy company work force projections which were utilized in the preparation of Scenario II population projections include companies with expansion and/or development plans and are as follows:

C-a Rio Blanco Oil Shale Project (Gulf and Standard)
C-b Cathedral Bluffs Shale Oil Company (Occidental and Tenneco)
Colony Oil Shale Project (Arco/Exxon and TOSCO)
Union Oil Shale Project
Superior Oil Shale and Minerals Project
Snow Mass/Anshutz Coal
Colowyo Coal
Northern Minerals Coal
New Coal (Leasing and Expansions as proposed as part of BLM's Hams-Fork Green River E.I.S.)
Ancillary Basic Response Development in Mesa County
Colorado Ute Power Plant
Utah International
GEX/CMC Coal
Sheridan Coal
Energy Fuels
Mid-Continent Mesa II
Moon Lake (Power Plant and Coal)
Storm King

The population projections contained within this report are an update of previously prepared growth monitoring efforts conducted by the Colorado West Area Council of Governments. Region XI of Colorado contains the counties of Rio Blanco, Garfield, Mesa, and Moffat. According to the 1977 Special Census, the Region's population was 101,051. Based upon "preliminary" 1980 U.S. Census housing data, there are 48,626 housing units in Region XI. At a three percent vacancy rate and by applying the 2.7 family multiplier (47,167 occupied units x 2.7), an unofficial CWACOG population estimate for Region XI produces a figure of 127,350 people in January 1980. This figure compared to the 101,051 1977

Special Census figure is illustrative of the type of growth the Region has been experiencing in only the beginning phases of oil shale development. With major oil shale development activities, the Region's population is anticipated to nearly double by 1985. Most of the growth will occur in the Grand Junction area of Mesa County. However, it is also anticipated that Garfield County, and in particular the City of Rifle, will experience the most dramatic growth by 1985. The already heavily growth impacted Moffat County/Craig area will continue to experience growth pressures, while Rio Blanco County, currently the smallest in population, could more than quadruple in population by 1985.

These projections clearly point to the need for extensive preparation in order to deal with the tremendous growth pressures generated by large scale energy developments. Each county within Region XI in conjunction with the Colorado West Area Council of Governments has initiated a comprehensive impact mitigation process. The impact mitigation process includes county and municipal comprehensive planning, capital improvements programming, and an impact committee structure comprised of county impact advisory groups and county core groups which assess community and county needs and resource requirements. The purpose of this report is to provide the best information available in facilitating the impact mitigation process within Region XI.

SPECIAL NOTE:

If you should have any questions concerning these population projections, please feel free to contact the Colorado West Area Council of Governments, Box 351, Rifle, CO 81650, (303/625-1723). Additional information can be made available on an individual basis, including such information as 1977 Census data, economic data, current population projections for elderly and school aged children, CWACOG Growth Monitoring Reports of previous years, and background information utilized in the compilation of this report.

GARFIELD COUNTY

1977 SPECIAL CENSUS	18800
1980 ESTIMATE FOR JANUARY 1	22162
HOUSING UNIT COUNT	9139

End of Year	I	II	III
1980	19985	23013	
1981	20524	27837	
1982	21264	36494	
1983	21709	45440	
1984	22247	53265	
1985	23178	55694	66126
1990	25823	64379	70967
1995	29731	68854	
2000	33911	75566	97873

CARBONDALE

1977 SPECIAL CENSUS	1644
1980 ESTIMATE FOR JANUARY 1	1945
HOUSING UNIT COUNT	829

End of Year	I	II
1980	1797	1970
1981	1992	2240
1982	2387	2795
1983	2487	2897
1984	2687	3100
1985	3287	3702
1990	4387	4815
1995	6887	7328
2000	9612	10066

GLENWOOD SPRINGS

1977 SPECIAL CENSUS	4091
1980 ESTIMATE FOR JANUARY 1	4283
HOUSING UNIT COUNT	2103

End of Year	I	II	III
1980	4315	4419	
1981	4391	4672	
1982	4465	5091	
1983	4539	5470	
1984	4609	5655	
1985	4676	5578	8098
1990	4977	5794	9493
1995	5240	6045	
2000	5529	6358	12841

NEW CASTLE

1977 SPECIAL CENSUS	543
1980 ESTIMATE FOR JANUARY 1	613
HOUSING UNIT COUNT	253

End of Year	I	II	III
1980	565	773	
1981	573	871	
1982	581	1025	
1983	588	1199	
1984	596	1317	
1985	603	1294	1449
1990	633	1515	1800
1995	664	1530	
2000	706	1598	2075

PARACHUTE

1977 SPECIAL CENSUS	377
1980 ESTIMATE FOR JANUARY 1	334
HOUSING UNIT COUNT	138

End of Year	I	II	III
1980	389	448	
1981	394	882	
1982	399	1364	
1983	405	1723	
1984	410	1865	
1985	416	1703	6142
1990	448	2508	11099
1995	482	2523	
2000	516	2618	16742

RIFLE

1977 SPECIAL CENSUS	2244
1980 ESTIMATE FOR JANUARY 1	3540
HOUSING UNIT COUNT	1352

End of Year	I	II	III
1980	2316	3933	
1981	2341	5661	
1982	2367	8492	
1983	2394	12516	
1984	2421	18113	
1985	2448	19573	22060
1990	2585	23710	23710
1995	2723	22934	
2000	2870	23687	25159

BATTLEMENT MESA

NEW COMMUNITY

End of Year	I	II	III
1980	0	589	NA
1981	0	2078	
1982	0	5499	
1983	0	8443	
1984	0	9170	
1985	0	9555	
1990	0	10644	
1995	0	12252	
2000	0	13979	

SILT

1977 SPECIAL CENSUS	859
1980 ESTIMATE FOR JANUARY 1	894
HOUSING UNIT COUNT	338

End of Year	I	II	III
1980	896	1079	
1981	912	1268	
1982	927	1547	
1983	943	1943	
1984	960	2297	
1985	977	2361	3392
1990	1066	2595	3621
1995	1152	2626	
2000	1232	2750	3934

GARFIELD BOC

End of Year	I	II	III
1980	9707	9792	
1981	9921	10165	
1982	10138	10681	
1983	10353	11249	
1984	10564	11748	
1985	10771	11928	20359
1990	11727	12798	20097
1995	12583	13616	
2000	13446	14510	26171

MESA COUNTY

1977 SPECIAL CENSUS 66848

1980 ESTIMATE FOR JANUARY 1 78793
HOUSING UNIT COUNT 32187

End of Year	I	II	III
1980	70687	79540	
1981	71992	82730	
1982	73301	90319	
1983	74614	99218	
1984	75921	111787	
1985	77221	118745	120156
1990	83428	132308	143854
1995	89231	137842	
2000	95128	145198	190484

GREATER GRAND JUNCTION *

GRAND JUNCTION CITY LIMITS

1977 SPECIAL CENSUS	25398
1980 ESTIMATE FOR JANUARY 1	28670
HOUSING UNIT COUNT	12444

End of Year	I	II
1980	56829	63826
1981	57908	66191
1982	58988	71943
1983	60067	78998
1984	61136	89144
1985	62193	94817
1990	67170	106040
1995	71781	110334
2000	76506	116216

* Figures include Grand Junction and surrounding unincorporated suburban area.

COLLBRAN

1977 SPECIAL CENSUS	293
1980 ESTIMATE FOR JANUARY 1	321
HOUSING UNIT COUNT	160

End of Year	I	II
1980	324	324
1981	340	340
1982	356	356
1983	372	372
1984	388	388
1985	404	404
1990	484	484
1995	565	565
2000	645	645

DE BEQUE

1977 SPECIAL CENSUS	264
1980 ESTIMATE FOR JANUARY 1	324
HOUSING UNIT COUNT	135

End of Year	I	II *	III
1980	268	325	
1981	272	428	
1982	276	657	
1983	280	872	
1984	285	945	
1985	290	795	1753
1990	315	757	1754
1995	339	772	
2000	361	807	2240

* Does not include possible Chevron Oil Shale project.

FRUITA

1977 SPECIAL CENSUS	2328
1980 ESTIMATE FOR JANUARY 1	3034
HOUSING UNIT COUNT	1032

End of Year	I	II
1980	2435	3810
1981	2473	4315
1982	2512	5413
1983	2551	6620
1984	2592	8509
1985	2633	9532
1990	2851	10884
1995	3030	11098
2000	3324	11634

PALISADE

1977 SPECIAL CENSUS	1083
1980 ESTIMATE FOR JANUARY 1	1437
HOUSING UNIT COUNT	680

End of Year	I	II	III
1980	1435	1687	
1981	1438	1704	
1982	1442	1889	
1983	1447	1996	
1984	1452	2157	
1985	1458	2261	3445
1990	1492	2354	9937
1995	1528	2416	
2000	1573	2488	13020

MESA 30C

End of Year	I	II
1980	10120	9892
1981	10301	10092
1982	10483	10417
1983	10669	10732
1984	10856	11032
1985	11047	11340
1990	12000	12273
1995	12903	13172
2000	13764	14053

RIO BLANCO COUNTY

1977 SPECIAL CENSUS	5100
1980 ESTIMATE FOR JANUARY 1	6090
HOUSING UNIT COUNT	2144

End of Year	I	II	III
1980	5324	6111	
1981	5402	9230	
1982	5480	12002	
1983	5558	14343	
1984	5635	16806	
1985	5710	19392	40501
1990	6067	25703	35881
1995	6382	25613	
2000	6678	26484	44302

MEEKER

1977 SPECIAL CENSUS	1848
1980 ESTIMATE FOR JANUARY 1	2606
HOUSING UNIT COUNT	950

End of Year	I	II	III
1980	1886	2615	
1981	1900	3650	
1982	1914	4861	
1983	1928	7031	
1984	1943	9077	
1985	1958	10693	16745
1990	2044	14179	14179
1995	2134	14104	
2000	2220	14548	16593

RANGELY

1977 SPECIAL CENSUS	1871
1980 ESTIMATE FOR JANUARY 1	1960
HOUSING UNIT COUNT	741

End of Year	I	II*	III
1980	2006	2026	
1981	2050	4049	
1982	2093	5517	
1983	2136	5602	
1984	2178	5919	
1985	2218	6826	14088
1990	2387	9539	10237
1995	2526	9428	
2000	2666	9774	12708

* Figures include the Moon Lake (Deseret) Coal Mine and Power Plant being located in the Rangely area.

RIO BLANCO BOC

End of Year	I	II	III
1980	1432	1470	
1981	1452	1531	
1982	1473	1624	
1983	1494	1710	
1984	1514	1810	
1985	1534	1873	9668
1990	1636	1985	11519
1995	1722	2081	
2000	1792	2162	15001

NOTE:

Moffat County figures still in process of being developed. If you desire to receive the Moffat County figures, please contact the CWACOG Office (625-1723).